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EVALUATION OF DEPOT MAINTENANCE HANDBOOK

Final Report

SwRI Project 17-7958-819

Prepared for

U.S. Army Aviation Systems Command
Depot Engineering and RCM Support Office
Corpus Christi Army Depot
Corpus Christi, Texas 78419

Performed as a Special Task under the auspices of the
Nondestructive Testing Information Analysis Center
Contract No. DLA900-84-C-0910, CLIN 0001AR

July 1986

SOUTHWEST RESEARCH INSTITUTE
SAN ANTONIO HOUSTON

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by

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Results are presented of the evaluation of the Depot Maintenance Handbook relative to the Corpus Christi Army Depot's modernization plans and particularly facility and resource requirements to support the new workload for overhauling, maintaining and inspecting the UH-60, the AH-64, the CH-47D, and OH-58D aircraft. The objective of this part of the investigation was to judge the adequacy of criteria and guidelines currently incorporated into the subject handbook based on review of the new workload and to provide additional criteria and standardized repair guidelines, as necessary. A description is also provided of the updated Data Analysis, Reporting and Documentation System (DARDS) including its operating procedures and NDI/ACE output products. The objective of this part of the effort was to develop and implement DARDS on an IBM PC/XT computer. DARDS is used for the analysis, reporting, and documentation of the ACE profile data in order to support AVSCOM depot engineering requirements and internal management services.

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FOREWORD

The work reported herein was performed for the U.S. Army Aviation Systems Command, Depot Engineering and Reliability Centered Maintenance Office in Corpus Christi, Texas. The work was directed at evaluating the Depot Maintenance Handbook recently published by the Nondestructive Testing Information Analysis Center (NTIAC) to assure its adequacy in light of the Army's Depot modernization plans and new workload for overhauling, maintaining, and inspecting Army aircraft at the Corpus Christi Army Depot (CCAD). In addition, AVSCOM's Data Analysis, Reporting and Documentation System (DARDS) was updated utilizing selected, pertinent and up-to-date information on depot maintenance and nondestructive inspection included in the Depot Maintenance Handbook.

The work was conducted as a Special Task under the auspices of the Nondestructive Testing Information Analysis Center at Southwest Research Institute under Contract No. DLA900-84-C-0910, CLIN 0001AR. Major portions of the investigation were performed under subcontracts by Mr. Ronald T. Anderson and Mr. Douglas C. Brauer at Reliability Technology Associates in Orland Park, Illinois. Work on updating the DARDS program was performed by Harold Y.H. Law and Joan W. Vandrey. Dr. George A. Matzkanin, Director of NTIAC, coordinated the effort at Southwest Research Institute and assisted in identifying nondestructive inspection methods relevant to the overhaul and maintenance of Army aircraft. At CCAD, the program was conducted under the technical management and guidance of Mr. Lew Neri, AMSAV-MR.

PREFACE

Results obtained during this NTIAC Special Task are presented in this Final Report in two parts. Part I is a summary report presenting the results of the evaluation of the Depot Maintenance Handbook relative to the Corpus Christi Army Depot's modernization plans and particularly facility and resource requirements to support the new workload for overhauling, maintaining, and inspecting the UH-60, the AH-64, the CH-47D, and OH-58D aircraft. The objective of the investigation was to judge the adequacy of criteria and guidelines currently incorporated into the subject handbook based on review of the new workload and to provide additional criteria and standardized repair guidelines, as necessary.

Part II is a report providing a description of the updated Data Analysis, Reporting and Documentation System (DARDS) including its operating procedures and NDI/ACE output products. The objective of the effort described in this report was to develop and implement DARDS on an IBM PC/XT computer. DARDS is used for the analysis, reporting, and documentation of the ACE profile data in order to support AVSCOM depot engineering requirements and internal management services. In addition to these two parts included in this Final Report, one copy of a floppy disk containing the programming set of DARDS was delivered to the AVSCOM personnel during the three-hour training session conducted as part of this effort at the Corpus Christi Army Depot.

PART I

EVALUATION OF DEPOT MAINTENANCE HANDBOOK

by

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1.0 INTRODUCTION

The subject Depot Maintenance Handbook provides information on standardized methods for the repair and acceptance of minor structural discrepancies and/or variations in parts and materials used in Army aircraft systems and components. This handbook defines common discrepant conditions, with limits as to where and to what extent repairs can be made, and it provides applicable repair instructions, with inspection crtieria indicating application of nondestructive testing to assure the design integrity and quality of the reconditioned items.

Because of the importance of the subject handbook in providing engineers with a practical, quick, reference document for preparing AVSCOM engineering directives and calls (AEDs/AECs) and for performing simple, cost-effective repairs and inspections on major failure modes encountered at the depot, it is essential that the handbook be kept up-to-date to ensure continued efficient and effective Army aviation system maintenance. This report summarizes the results of RTA's evaluation of the handbook relative to the Corpus Christi Army Depot's modernization plans (reference 2) and particularly facility and resource requirements to support the new workload for overhualing, maintaining and inspecting the UH-60, the AH-64, the CH-47D, and OH-58D aircraft. The objective of the investigation was to judge the adequacy of criteria and guidelines currently incorporated into the subject handbook based on review of the new workload and to provide additional criteria and standardized repair guidelines, as necessary.

Performing the effort involved meeting with cognizant engineering personnel, from AVSCOM's Depot Engineering and RCM Support Office (AMSAV-7), several times during the course of the investigation to identify specific plans for providing improved depot repair and processing capabilities to support CCAD in response to the new workload. This included reviewing the AMSAV-7 office mission and functions, describing some of their key tasks planned in support of their missions and functions in view of projected depot workload requirements, and reviewing action plans/scheduled milestones for implementing the improved capabilities.

The results of this evaluation presented in Section 2.0 are based on a review of the information obtained at the above meetings.

2.0 RESULTS

2.1 AMSAV-7 Mission and Functions

The mission of AMSAV-7 is to accomplish depot support and reliability centered maintenance (RCM) engineering throughout the material life-cycle. It serves as the AVSCOM technical focal point for the RCM Airframe Condition Evaluation (ACE) and Aircraft Analytical Corrosion Evaluation (AACE) programs in support of the AVSCOM program manager. The office has for years provided essential engineering functions and insights to all levels of the Army maintenance program with special emphasis at the depot maintenance level. The role performed by AMSAV-7 is in a progressive state of evolution and has matured to the point where it is very effective in responding to depot needs. It is in this light that the dependence of the depot on the office is realized, that its capabilities, functions, and resources must be continually modified and expanded relative to both near and long term work projections. Real, near and long term office issues focus on:

1. Providing proper and adequate staffing
2. Expanding organizational structure
3. Increasing response time from servicing organizations
4. Increasing office authority and visibility within AVSCOM Headquarters
5. Resolving funding management conflicts between Directorate of Engineering and Maintenance
6. Providing modern accommodating facilities

The AMSAV-7 office consists of an organizational structure designed to effectively support the depot maintenance environment. It is structured to deal directly with specific technical areas in the planning and performance of maintenance support. Figure 2-1 presents the AMSAV-7 office organizational structure and provides a brief description of its mission and functions.

2.2 AMSAV-7 Tasks

Many of AMSAV-7 existing or near term tasks reflect new concepts and methodologies. These tasks include:

- Breakout Support
- Army Oil Analysis Program (AOAP)
- ACE/AACE
- DMWR Scrub
- Reliability-Centered Maintenance
- Phase Maintenance (Progressive)
- DMWR Preparation Effort
- Data Preparation
- Robotics Applications, Studies, and Automation
- Engineering Support in Analytical Investigation
- Material and Process Studies
- Ground Support Equipment
- EIR Exhibits
- Value Engineering
- Test Measurement and Diagnostic Equipment (TMDE)

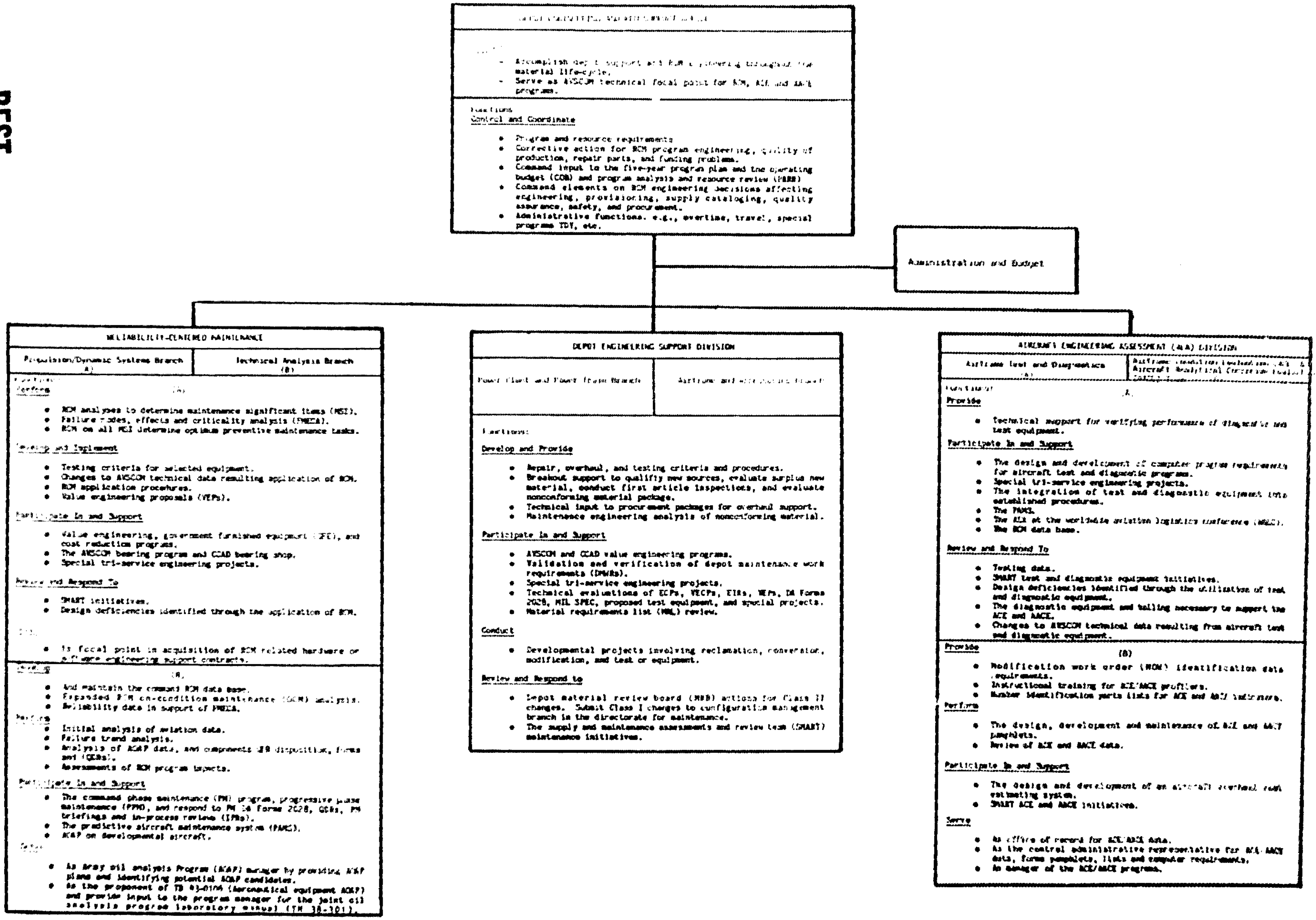

Figure 2-1 Depot Engineering and RCM Support Office Organizational Structure

Some of the more pertinent tasks are described in the following paragraphs:

Breakout Support

This task is to support AVSCOM's Breakout Program by providing an effective and viable test and evaluation function for qualifying new replenishment spare parts produced by suppliers, other than the original manufacturers. The function will focus on critical, short life, engine and power transfer parts used in current operational helicopters and especially on those which have an established need for high levels of maintenance both preventative and corrective.

The objective of the Breakout Program is to reduce costs by purchasing parts from other than prime weapon system contractors while maintaining the integrity of the system and equipment in which the parts are to be used. The program is based on the application of sound management and engineering judgment in (1) determining the feasibility of acquiring parts by competitive procedures or direct purchase, and (2) overcoming or removing constraints to breakout identified through the screening process (technical review) described by DAR, Supplement No. 6, "DoD Replenishment Parts Breakout Program".

Breakout is an engineering action which results in the optimum procurement method code being assigned to a spare part. This action invites the maximum competition consistent with good engineering and business practices, which normally result in lower costs for the Army, earlier availability of the hardware and greater opportunity for small business. These direct benefits also produce side benefits due to shorter pipelines which require less funds to fill and increase the production base to support emergency requirements.

An often overlooked aspect of spare part procurement is the assurance that the spares are qualified and have the equivalent "as-delivered" reliability as the original hardware. Qualification is the process by which parts are obtained from manufacturers, examined, tested, and then identified on a list of qualified parts. The purpose of parts qualification is, prior to and independent of any procurement action, to provide a means of relieving quality conformance inspections of long, complex, or expensive tests. In many cases it has been found that spares have not been rigorously qualified and did not receive a conformance inspection and screening equivalent to that accorded the originally manufactured part. Consequently, spares with poor quality and reliability have been delivered and used for replacement. AMSAV-7 plans to implement a rigorous reliability qualification program of spares, in support of the breakout program, in a similiar manner as the initial components are qualified. Particular emphasis will be given to spares purchased from other than the prime contractors.

ACE/AACE

AMSAV-7 is AVSCOM's technical focal point for the ACE/AACE programs. The objective of the ACE/AACE program is to provide a meaningful and inexpensive method for ranking the aircraft within the fleet as candidates for depot level maintenance. It involves a particular approach to on-condition maintenance in which the state of an aircraft is deduced from a carefully designed profiling technique which can be effectively carried out by trained personnel.

Through the ACE/AACE program, the aircraft which need repair or reconditioning are identified using a noninvasive technique. The technique used in ACE involves an evaluation of the structural integrity of the aircraft in terms of certain are selected parameters, called indicators. Typical indicators include the condition of the main lift beam, the nose fuselage skin, and the upper bulkhead, and the state of the corrosion protection. Weights are then assigned to each of the indicators using ranking and distribution techniques.

AACE, as a companion to ACE, provides a method of selecting aircraft as corrosion candidates for depot level repair. The basic aircraft structure is examined for corrosion defects together with an assessment of the external areas of components, both structural and dynamic, for deteroriation caused by corrosion. AACE pertains principally to fuselage structural members that are replaceable at the depot, but also pertains to dynamic components and component structures.

DMWR Scrub

AMSAV-7 performs an on-going effort to systematically screen existing U.S. Army Aviation Depot Maintenance Work Requirements (DMWRs) for the purpose of: (1) eliminating unnecessary tasks during depot maintenance and (2) eliminating arbitrary remanufacture through the development of extended wear limits and reclamation procedures for piece parts. This task involves the review of selected DMWRs and the preparation of AVSCOM Engineering Directives (AEDs) for their revision, based on application of Non-Destructive Inspection (NDI) and Reliability Centered Maintenance (RCM) concepts. The intent is to insure that the inherent design reliability and safety of the items reviewed are achieved with the performance of the least amount of maintenance.

To achieve the above objectives, DMWRs are evaluated for areas where preshop analysis (PSA) can be used to determine the extent of maintenance needed. DMWRs are grouped into three main categories: Category I: Aircraft - This category encompasses the total aircraft; for example, the airframe, electrical wiring, seats, transparencies, push-pull systems and doors; Category II: Large Components - This category encompasses large components and major assemblies; for example, engines and transmissions; and Category III; Small Components - This category encompasses small components and accessories; for example, generators, hydraulic pumps and oil coolers.

PSA is a logical inspection process that is done in conjunction with equipment disassembly. Components are disassembled to the subassembly level with the PSA team focusing on the reason(s) why the item was sent to the depot and component operating times. PSA specifies the extent of further disassembly and repair needed to be performed at the appropriate prime shop(s) and determines if component "short routing" can occur, i.e. if components can be sent directly to the control holding area or assembly lines. Defined weak spots within a component must be accessed to inspect for specified historically common deficiences.

PSA for Category I items is conducted to determine the degree of disassembly required. This includes removal of all Category II and III items, tailboom, appropriate panels, and doors. After the aircraft is disassembled and PSA is completed, the airframe and airframe components (for example, tailboom, skids, panels, and doors) are routed to their appropriate prime shop. The Category II and III items are not repaired; these items are routed into a holding area or subjected to preservation and storage.

PSA for Category II items is conducted while removing all acessory items and disassembling the basic component into subassemblies/modules. PSA identifies the high confidence subassemblies/modules that can complete processing without further disassembly or with only partial disassembly. The accessory items are forwarded to their respective prime shop for check and test. Only minor repairs are allowed to address deficiencies; otherwise the assemblies are turned into supply as repairables and scheduled for maintenance. The subassemblies/modules of the basic component are forwarded to their respective prime shops for disassembly and processing.

For Category III items there is no advantage to a PSA since, in any case, complete disassembly is required. These components are normally inducted into their respective prime shops where they are completely repaired/overhauled. Only those piece-parts requiring further repair (for example, machining, plating, or welding) are routed from the prime shop to a specialty shop.

Reliability-Centered Maintenance

AMSAV-7 performs RCM engineering analysis on selected aircraft systems and components. RCM is a systematic analysis of reliability and safety data to identify maintenance problem areas for design review consideration, and to establish the most effective preventive maintenance program. RCM logic is applied to the individual failure modes of each repairable component identified by FTA/FMECA, through a progressive determination of how impending failures can be detected and corrected in order to preserve, to the degree possible, the inherent levels of reliability and safety designed in the item.

RCM logic data is a major input to the ILS and trade-off process and appears primarily on the LSAR "B" sheet. "B" sheet data is used in preparing other LSAR sheets. The end result of the complete ILS/RCM process is the compliation of a Provisioning Master Record (PMR) from which procurement of support items is derived.

Note that the ILS/RCM process is initiated early to affect design and operational concepts; identify the gross logistic resource requirements of alternative concepts; and to relate design, operational, manpower, and support characteristics to readiness objectives and goals. Optimization of the support system is achieved through allocations of functions and tasks to specific maintenance levels, repair vs discard analysis of components and parts, formulating design recommendations to reduce maintenance times or to eliminate special support requirements, etc. Resulting data is used as direct input into, or as source information for, the development of data products associated with each ILS element such as provisioning list, technical manuals, personnel and training requirements information, etc. This assures compatability between ILS element documents and permits common use of data which apply to more than one logistic element.

AMSAV-7 integrates in an efficient way many of the relevant assurance programs (i.e., reliability, maintainability and safety) and other special studies which also serve the common objective of orienting the development and operational phases toward a practical, serviceable and affordable product. It provides output data for preparation of optimum maintenance requirements for achieiving, restoring, or maintaining an item's operational capability. The requirements are generally defined early during the design phase based on initial ILS plans and RCM analyses and updated as necessary during the course of the development program and is reassessed as part of a sustaining engineering effort to reflect actual field experience data. The maintenance tasks planned for execution at AVUM, AVIM and at the Depot are defined and logistic support requirements are formulated. This includes:

a. Maintenance tasks
   - Lubrication/servicing
   - Operational checks
   - Inspection/functional checks
   - Rework
     - Repair

- Overhaul
- Rebuild
• Replacement

b. LSAR-B maintenance classifications
   • Hard Time
   • On Condition
   • Condition Monitoring

c. Tools and test equipment and calibration requirements

d. DMWRS

e. Programmed Depot Maintenance

f. Phase maintenance

g. Maintenance task frequencies/intervals

Depot Maintenance Work Requirement (DMWR) Preparation

AMSAV-7 is responsible for the technical content and currency of aviation and related ground support equipment DMWRs. A DMWR is a comprehensive document which defines the minimum procedures and standards required to process a component or end item through the depot. It is normally provided as the "Statement of Work" for each item contracted or programmed for depot level maintenance. It is a "how to do" type of document which provides the necessary instructions for the complete overhaul of the item, including conversion/modification criteria and piece-part reclamation procedures for the worse case conditions of applicable parts.

The induction of new and modified equipment components and parts into the depot requires a concerted effort to maintain accurate and current DMWRs. This entails reflecting the depot maintenance functions shown in applicable maintenance allocation charts (MACs) and formatted in light of MIL-M-63041B(TM), Preparation of DMWRs. DMWR content includes technical support requirements; preshop analysis operations/checklists; overhaul operations; quality assurance requirements; preservation, packing and marking requirements; repair parts and special tools list; expendable supplies and materials list; and depot mobilizational requirements.

DMWRs are supplemented in the depot by AVSCOM Engineering Directives (AEDs) where an AED addresses a specific problem in a DMWR and can also be used to support depot programs independent of DMWRs. AEDs also serve as an aid in updating DMWRs.

Data Preparation

The performance of RCM engineering analyses as well as other depot support tasks requires the availability of an extensive and cumulative base of data and information. Consequently, AMSAV-7 compiles data for this purpose and maintains a complete on-going RCM data base. The data is continually refined and updated to include the most recent field experience information. Some of the essential data items and key numerics that are derived from the RCM data base are described below.

MTBF numerics are derived from the field experience data in the RCM data base and used to determine basic part replacement rates and can be directly inputted to logistics analyses and trade-off studies of alternative designs. Similarly, MTTR numerics are derived from the field data and used to determine (via the ILS process) the number of people required to maintain a given number of systems within a specified time period. Maintenance engineering data allows decisions to be made regarding difficulty of maintenance (which translates into personnel skill levels), tools and equipment required, consumable items used while performing maintenance, and facilities required.

Key to RCM engineering and other depot support tasks is Failure Mode Analysis based on Fault Tree Analysis (FTA) or Failure Modes, Effects, and Criticality Analysis (FMECA) procedures. Regardless which technique is applied the objective is to identify the likely modes of failure, their effects and criticality based on experience data derived from the RCM data base.

EIR Exhibits

The objective of the Equipment Improvement Recommendation (EIR) program is to ensure that material failures at operational units and user recommendations for improvement are addressed by technical and procurement activities. The EIR program provides a means to ensure that suitable attention is given to those failures and recommendations and that they are analyzed and used as a source of information for subsequent management actions. Specifically, the EIR program allows for prompt long term corrective action for reported failures and faults in Army products by means of Engineering Change Proposals (ECP), Product-Improvement Proposals (PIP), or Modification Work Orders (MWO).

As part of the EIR process engineering exhibits may be sent to the depot for teardown analysis. With the large number of EIR's submitted and subsequent exhibits, it is important to monitor more closely the status of the exhibits sent to the depot. AMSAV-7 serves as the action point for exhibit control and status tracking.

It should be noted that AMSAV-7 depot support and RCM engineering tasks are performed in recognition of the availability of CCAD's unique capabilities which are not found in any other depot. These capabilities are as follows:

- Two electron beam (EB) welders used to weld dissimilar and exotic aircraft metals. These EB welders have the ability to repair many parts which would otherwise require replacement.
- Eight modern computer-assisted turbine engine test cells for 100 to 5000 horsepower engine testing.
- An automated circuit analyzer for performing high-speed continuity and electrical resistance tests providing results in the form of hard-copy printouts. The system can test up to 10,000 circuits in 30 minutes.
- Plasma arc spraying for building up worn parts which are then machined to specification, thereby reclaiming the parts.
- Industrial x-ray inspection of main rotor blades for bonding voids and internal pockets of water accomplished using a real-time radiography x-ray of the blade surface. The system provides instantaneous x-ray viewing as well as a permanent videotape record of each blade's condition.
- A bearing rework facility containing 16,000 square feet of environmentally controlled shop space where cleaning, inspection, repair of active/inactive surfaces, replacement of rolling elements, rework or replacement of retainers and interchange components, and micro-honing of inner and outer races is accomplished. The CCAD bearing facility is the most modern bearing rework facility within the DoD.
- Four electrical discharge machines for removing metal between

the workpiece and a shaped carbon electrode. This process is applicable to small and intricate parts. These machines are particularly effective for processes such as removing damaged vanes from power turbine assemblies.

- Spectrometric oil analysis for Army, National Guard, Navy, and other Federal agencies. A direct reading emission spectrometer capable of analyzing an oil sample for 20 wear-metal elements in 55 seconds gives aviation operating units advance notice of components about to fall.
- Several transmission test cells for full load testing of the CH-47, UH-1, AH-1, OH-6, and OH-58 transmissions. New transmission test cells are near completion and final acceptance by the Army for the Black Hawk and Apache transmissions.
- A helicopter blade test facility for aero-dynamic testing of Black Hawk and Apache composite blades.

2.3 Depot Workload Requirements

CCAD presently performs repair, overhaul, modification, and retrofit of airframes, aircraft components, systems, subsystems and related items for the UH-1, AH-1, OH-6, OH-58 and CH-47 rotary aircraft. Future weapon systems to be supported by CCAD include the CH-47D, AH-64, OH-58D, and UH-60 rotary aircraft and selected parts of the AGT 1500 turbine shaft engine. A brief summary descriptions of these future weapon systems are given in the following paragraphs. Full plans for supporting this increase in workload at CCAD are given in Reference 2. Table 2-1 provides projected dates for the induction of the new systems at CCAD.

Table 2-1 Projected Aircraft Workload Overview

AIRCRAFT ITEM			
AIRCRAFT	AIRFRAME	ENGINE	COMPONENTS
CH-47D	FY 88	FY 84	FY 88
OH-58D	JUL 88	JUL 88	JUL 88
UH-60A	OCT 86	OCT 84	FY 85--partial FY 87—complete
AH-64A	OCT 88	OCT 87	OCT 87

<u>CH-47D, Chinook Helicopter</u>: The present CH-47 fleet of A, B, and C models will be modernized to one standard configuration (CH-47D) which will facilitate logistical support and simplify maintenance support. The CH-47D Chinook is a twin turbine engine, tandem rotor helicopter designed for internal and external cargo transport during visual and instrument, day and night operations. The D model is a result of incorporating new technology in remanufactured CH-47A, B, and C model helicopters. Design improvements have resulted in improved reliabliity, availability, maintainability, and survivability. The CH-47D will provide the Army with the necessary Medium

Lift Helicopter (MLH) that can accomplish missions throughout the range of temperature/altitude combinations where United States forces can reasonably be expected to operate. The program will produce a fleet of CH-47 helicopters with low level terrain flgiht tactics capability and increased night instrument meteorological conditons (IMC) operations capability which are dictated by postulated threats.

OH-58D Kiowa Observation Helicopter: The OH-058D shall use the basic airframe of the Bell Helicopter OH-58 with modifications. The OH-58 incorporates a mast-mounted sight (MMS) sub-system designed as an aerial surveillance system for day/night acquisition of enemy targets. The OH-58D performs day and night close aero-scout and field artillery aerial observer missions world-wide under a variety of environmental and threat conditions. The OH-58D will be assigned as an aero-scout helicopter for attack helicopter companies and air calvalry troops and as a field artillery aerial observation helicopter.

UH-60A Black Hawk Helicopter: The Black Hawk is a twin-turbine, medium speed, single main rotor configured helicopter capable of transporting cargo, 11 combat troops, and weapons during day, night, visual and insturment conditions. The main and tail rotors are both four-bladed, with a capability of manual main rotor blade folding, tail rotor blade scissoring, and tail pylon folding. The aircraft is powered by two T700 General Electric 1543 SHP turbine engines, and has a flight endurance time of 2.3 hours at 4,000 feet altitude and 95 degrees fahrenheit. The Black Hawk will replace the UH-1 in air assault, air calvalry, and aeromedical evacuation missions. The Black Hawk was designed to transport troops and equipment into combat, resupply these troops while in combat, and perform associated functions of aeromedical evacuation repositioning of reserves, and other combat support missions. Increased cost effectiveness will be achieved through substantially improved maintainability, reliability, survivability, and performance. Organic depot ILS support includes DMWR validation/verification, special equipment and tooling evaluation, coordination of depot training, and pilot overhaul evaluation.

AH-64A Apache Helicopter: The AH-64A is a twin enginer helicopter designed as a stable, manned aerial weapons system to deliver aerial point and area and rocket target firepower. Developed to be the most lethal and survivable helicopter in aviation history, the AH-64 will augment the Combined Arms Team with improved folding Fin 2.75 Aerial Rockets, 30mm Connon, and the anti-armor HELLFIRE Missile. Teh AH-64A will perform its assigned missions by providing direct aerial fire support under day, night, and marginal weather conditions. Typical AH-64A combat missions include anti armor, air cavalry operations, and escort and fire supportfor airmobile operations. AH-64A peacetime missions include aviator and unit training, mobilization, and development of new and improved attack helicopter concepts. Organic depot support is targeted for October 1987. Projected organic depot ILS support includes Logistics Support Aircraft Readiness (LSAR) reviews, DMWR validation/verification, tooling evaluation, depot training, and pilot overhaul evaluation.

Selected Parts of the AGT 1500 Turbine Shaft Engines: The XM-1 tank is powered by an AGT 1500 SHP turbine engine. The depot will support the reclamation of selective parts that require special equipment and processes that are not available at other depots. The list processes that are not available at other depots. The list of parts and special equipment and processes that the depot has available to support the reclamation is shown below in Table 2-2.

Table 2-2 Selected Engine Parts To Be Repaired By The Depot

PART	PROCESS REQUIRED
STATOR VANE (5 low & 4 high pressure)	Electric Discharge Machining Vacuum Brazing
TURBINE WHEELS (1st thru 4th)	Plasma Spray Precision Balancing
TURBINE NOZZLES (1st, 2nd, & 4th)	Electric Discharge Machining Vacuum Brazing Plasma Spray
TURBINE SHAFT	Electron Beam Weld
BEARING HOUSINGS	Electron Beam Weld
TURBINE CYCLINDER	Plasma Spray
SHROUD ASSEMBLY	Plasma Spray
BEARINGS (ALL)	Complete Bearing Rework
POWER TURBINE HOUSING ASSEMBLY	Electric Discharge Machining Vacuum Brazing Plasma Spray

The large increase in workload due to the new systems described above results in the need to modernize and expand the existing shops and to construct new facilities. The Black Hawk and Apache are both larger in size than the present systems being overhauled. The manufacturing shops must be able to accommodate not only the increased workload but larger airframes, engines, transmissions, rotor heads, and many other components. Increased shop space is not the only requirement for the support of these sophisticated new weapon systems. State-of-the-art equipment is required to work on the new materials used and to test the technologically advanced systems in these aircraft. It is imparative that these new systems are provisioned for in terms of depot maintenance. The airframe, engine, power train, mechanical and hydraulic components of these aircraft differ widely from the UH/AH/OH aircraft common to the CCAD depot workload. CCAD will continue to provide depot level support to its existing assigned aircraft while integrating the new systems into the depot for support.

Accordingly, AMSAV-7 must also modernize to effectively support this increased workload and to provide the required RCM data base, to analyze equipment failure modes and trends, to develop equipment preventative and corrective maintenance plans, to develop equipment overhaul and repair procedures, to evaluate modified and new equipment, to qualify new vendors, to scrub DMWRs, to evaluate airframe condition requirements and to analyze aircraft corrosion. The subject handbook must be revised to reflect new depot processes as well as the concepts, techniques and programs planned by AMSAV-7 to improve productivity in response to the new workload.

3.0 Handbook Actions

The Depot Maintenance Handbook, being recently published, remains adequate to meet the current needs of the Depot Engineering and RCM Support Office. The depot level repair guidelines given in Section 3.0 do not need to be modified relative to near term modernization efforts. However, the modernization efforts by both CCAD and the AMSAV-7 office will require revising Section 2.0 of the handbook to include descriptions of new depot processes, techniques and repair capabilities planned and developed for support of the new workload as well as the new AMSAV-7 concepts and techniques developed to improve productivity. Revision of the handbook will assist in assuring the timely scheduling, funding, and execution of anticipated Military Construction Army (MCA), Facilitary Engineering Plan (FEP), and equipment plans.

Specific areas to be covered in the next revision of the handbook include:

1. The DMWR preparation process and particularly improved PSA criteria and guidelines resulting from the RCM Scrub Task.
2. The application of environmental stress screening (ESS) to the depot overhaul process.
3. The spare part qualification process.
4. The RCM data collection and feedback process.
5. EIR engineering exhibit teardown analysis and tracking process.

Techniques have been developed with respect to these areas and will be described in the handbook upon the first printing revision.

PART II

DATA ANALYSIS, REPORTING AND DOCUMENTATION SYSTEM (DARDS)

by

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1.0 INTRODUCTION

Data analysis, reporting and documentation is an integrated and important element in the services provided by the Depot Engineering and Reliability Centered Maintenance (RCM) Support Office for the Corpus Christi Army Depot (CCAD) and the Army Aviation System Command (AVSCOM). This service is particularly true in the Airframe Condition Evaluation (ACE) Program (Reference 1). The results of data analysis, interpretation, and presentation have immediate and significant impacts on depot management, engineering support, maintenance, and corrective actions. Useful information can be extracted from data through skillful analysis, presentation, and documentation. Only then can future workloads and corrective actions be identified and implemented in a timely and efficient manner. Such actions will impact on the improvement of depot engineering control and planning, including identification of design deficiencies, product improvements, and engineering change proposals. Therefore, a careful investigation on the analysis, reporting, and documentation of the ACE data is essential.

1.1 OBJECTIVE

The objective of this effort is to develop and implement an engineering and management support system, call Data Analysis, Reporting and Documentation System (DARDS), on an IBM PC/XT computer. It is used for the analysis, reporting, and documentation of the ACE profile data in order to support AVSCOM depot engineering requirements and internal management services. The basic structure of this system can be expanded in the future for a broader support to include RCM and Depot Maintenance Work Requirement (DMWR) data.

1.2 APPROACH

In order to achieve the objective, the following approach was taken. This approach included the following efforts:

1. Review and develop software structure, data base structure, data entry, input/output formats, and storage requirements for the ACE profile data in accordance with the ACE methodology.

2. Establish data structure, data files, software modules, and interfaces to handle the ACE data flow. These features have to be compatible with the ACE profile data corresponding to indicator and condition codes and the ACE input/output data format.

3. Conduct testing of software with current ACE profiling data which was provided by AVSCOM to ensure correct system performance.

4. Document the DARDS operating procedures and conduct one training session for AVSCOM's personnel in its operation.

2.0 OVERVIEW OF ACE

An objective of the Army aviation maintenance effort is to perform aircraft maintenance at the minimum practical cost without causing deterioration of the inherent design levels of reliability and safety. With the need for increased operational readiness as a prime driver, various studies by the military services and the airlines have shown that one of the better ways of achieving high readiness rates is by reducing unnecessary maintenance actions on aircraft. Requirements which increase maintenance costs, without a corresponding increase in safety and reliability, need to be identified and eliminated. The development and implementation of current Army aviation maintenance programs have been directed toward that end.

Army aviation depot level support facilities are maintained in order to respond to modifications, crash and battle damage, and any other deterioration of the airframe that is not practical to repair in the field. The major dynamic components that control the aircraft's flight characteristics are interchangeable at field level. However, the airframe has few major parts that can be replaced in the field, though temporary repairs are possible. It is the deterioration or degradation of the basic airframe and its substructure that creates the need for return to depot. With a 20 plus years expected life, the airframe in the field is impacted by a myriad of factors involving environment and mission utilization, ranging from infield storage with no maintenance to the other extreme of high utilization with contractor support. Consequently, there is a range of things that can go wrong with the airframe.

The Airframe Condition Evaluation (ACE) program was established to evaluate aircraft structural integrity. The objective of this program is to identify candidates for timely depot level repairs, in order to improve aircraft availability at minimum cost yet without causing deterioration of reliability and safety. The report addresses the Army's approach in dealing with this complex problem - its past experience, its current method of on-condition maintenance through profiling the condition of the airframes, and its enhancements.

The Airframe Condition Evaluation (ACE) program was established in 1973 to provide cost-effective criteria methodology and procedures for determining when to recall for depot level airframe maintenance on Army aircraft. Prior to 1973 the Army depot induction requirements for aircraft were prescribed at five-year intervals. Between 1967 and 1973, data were collected and reviewed in an effort to justify or revise this five-year cyclic requirement. The information showed that there was little correlation between the aircraft's condition and it accumulated flying hours or calendar time that could justify the five-year cyclic requirement. These data also showed that much of the work done during this cyclic depot return could have been accomplished in the field.

As a result, the Army strove to develop a more efficient method of aircraft depot induction during a peacetime environment. At the same time, however, the tight budgets and rising escalation of the Seventies demanded not only an efficient method but a more cost-effective solution to the problem - one that would reduce costs without allowing deterioration of safety, reliability or operational readiness. The reduction of unnecessary depot maintenance seemed to be the solution to reduce costs an to increase operational readiness.

The ACE program replaces the five-year cyclic overhaul system by a procedure which selects aircraft candidates for depot maintenance on an as-needed, "worst-case first" basis. ACE is a true On-Condition Maintenance (OCM) program. The ACE procedure profiles the condition of the airframe's structural integrity by evaluating representative indicators of deterioration or symptoms of distress. Each aircraft is profiled and a numerical score or index is assigned to that aircraft, based on its preselected indicators and the profiled condition. Aircraft are then ranked by this index. A profiling threshold is established for each aircraft Major Design Series (MDS) type to aid in candidate selection. Aircraft with index exceeding the established threshold are marked as candidates for depot maintenance. This procedure is done at minimum cost, without causing deterioration of the inherent design levels of reliability and safety. The ACE program is currently under the U.S. Army Aviation Systems Command (AVSCOM). References may refer to the U.S. Troop Support and Aviation Readiness Command (TSARCOM) which the program belonged during 1977-1983.

2.1 ACE METHODOLOGY

On-Condition Maintenance (OCM) is the concept born out of a need for increased efficiency, safety, productivity, and availability within austere budget constraints. OCM is a program where aircraft return to the depot on an as-needed basis, determined by an evaluation of the condition of the airframe. OCM's goal is to prevent the unnecessary maintenance which may occur in isochronic systems. It is not "if it's not broke, don't fix it", which excludes preventative maintenance. OCM involves the (1) evaluation of the structural integrity of the fielded aircraft, considering the myriad of factors impacting it; (2) selection of aircraft candidates for depot level repair; and (3) recall and issuance of aircraft through the depot.

The OCM concept utilizes a profiling technique in evaluating the condition of the aircraft and identifying the items most in need of depot attention. This is known as the Airframe Condition Evaluation (ACE) Program. As its name implies, ACE evaluates airframes only, not components which can be replaced and repaired in the field. This program selects a representative list of indicators of symptoms of distress for each aircraft Major Design Series (MDS) type. Weights are then assigned to each indicator for varying degrees of severity of degradation. With this as a basis, a trained ACE team evaluates each operational aircraft annually and profiles each aircraft by marking any faulty indicators by their worst condition code (degree of severity) on an ACE evaluation worksheet. The weights assigned to these profiles are then cumulated for each aircraft to develop the aircraft's profile index (PI), a numerical representation of the condition of the aircraft. These profile indices can then be ranked on a priority-of-need, and any aircraft with a PI exceeding a minimal profile index (or threshold) is identified as a candidate for return to depot.

2.1.1 Indicator and Condition Code Selection

Many areas of an aircraft cannot be fully analyzed without disassembly of the airframe, and in some cases may require special tooling or equipment too cumbersome to carry in the field. Hence under the OCM/ACE concept, only indicators of deterioration or degradation of airframe integrity are considered. Engineers at the Reliability Center Maintenance and Depot Engineering Support Branch (RCM&DESB) AVSCOM, with extensive experience on specific aircraft systems develop a list of indicators for each aircraft MDS type. Evaluation of these indicators then provides the condition of the aircraft structure. Typical indicators include primary and secondary airframe structures and hardpoints, such as the main lift beam, nose fuselage skin, upper bulkhead, cargo door tracks, and paint condition. As an example, the UH-1H/V indicator list is shown in Figure 1. Some of these indicators may sound insignificant by themselves; however, found faulty, they may be an indication of more severe problems. For example, a cracked cargo door track could mean misalignment problems, and a poor paint condition could be caused by corrosion. If left to deteriorate, these could cause potentially severe repair or safety problems.

Potential indicators should be accessible. Faults of the indicators should be frequent and easily detected, and the evaluation process for detecting the faults should be simple and repeatable for consistency. Also, these indicators are to be signs of need for depot repair, not field repair, so depot drivers such as material, labor, facilities, and expertise are to be considered. Total evaluation of all the indicators should take no longer than 30-60 minutes per aircraft, with minimal or

Figure 1

ACE Evaluation Worksheet for the UH-1H/V
from AVSCOM Pam 750-1, Appendix A

C1, TSARCOM PAM 750-1(1)

APPENDIX A

AIRFRAME CONDITION EVALUATION (ACE) UH-1H/V TSARCOM 750-1(1)	MASTER	EAM	UNIT	AREA	LOCATION

CARD COL.	PROFILE	INDICATOR NOMENCLATURE	ITEM REF.	
01	V X	TYPE/MODEL/SERIES	1.	AIRCRAFT SERIAL NO.
02-08		SERIAL NUMBER	2.	
09		SPECIAL MISSION	3.	
10		MAJOR COMMAND	4.	
11-12		GEOGRAPHICAL LOCATION	5.	
13-16		JULIAN DATE OF ACE	6.	
17	N O	A/C NEW OR OVERHAULED	7.	
18	C N S P K	O/H BY	8.	
19-22		A/C HOURS AT TIME OF OVERHAUL	9.	
23-26		JULIAN DATE OF OVERHAUL	10.	
27-30		TOTAL HOURS ON A/C	11.	
31	C K L M	OVERALL CONDITION	12.	
32	C K L M	PAINT CONDITION	13.	
33	B Y E R	DOORPOST L/H	14.	
34	E C Y R	WIRING, CIRCUIT BREAKER PANEL	-26.	
35	Y E A R	CARGO DOOR TRACKS L/H	15.	
36	S C Y J D U R	FWD MAIN BEAM HONEYCOMB PANEL L/H	16.	
37	S C Y J D U R	FWD MAIN BEAM HONEYCOMB PANEL R/H	16.	
38	Z T E G R	LIFT BEAM FORE & AFT WEBS & LOOSE HI-SHEAR	17.	
39	G B E R	PYLON ASSY HORIZONTAL WEB L/H	18.	
40	G B E R	PYLON ASSY HORIZONTAL WEB R/H	18.	
41	G R	PYLON RIVETS L/H	19.	
42	G R	PYLON RIVETS R/H	19.	
43	S C Y J D U R	PYLON HONEYCOMB PANEL FWD L/H	16.	
44	S C Y J D U R	PYLON HONEYCOMB PANEL AFT L/H	16.	
45	S C Y J D U R	PYLON HONEYCOMB PANEL FWD R/H	16.	
46	S C Y J D U R	PYLON HONEYCOMB PANEL AFT R/H	16.	
47	S C Y J D U R	LOWER AFT CABIN BULKHEAD L/H	16.	
48	S C Y J D U R	UPPER AFT CABIN BULKHEAD L/H	16.	
49	D I R	ANGLE & FWD FIRE WALL L/H&R/H FS 160-166	20.	ACE FY
50	S C Y J D U R	WORK DECK HONEYCOMB PANEL L/H	16.	
51	S C Y J D U R	CENTER SERVICE (ENGINE) DECK	16.	
52	S C Y J D U R	ROOF DECK HONEYCOMB PANEL, CENTER	16.	
53	S C Y J D U R	ROOF DECK HONEYCOMB PANEL, L/H	16.	
54	S C Y J D U R	ROOF DECK HONEYCOMB PANEL, R/H	16.	
55	S C Y J D U R	AFT OUTBOARD FUEL CELL BULKHEAD L/H	16.	
56	S C Y J D U R	MAIN BEAM AFT L/H	16.	
57	E C Y R	WIRE BUNDLES, AVIONICS COMPARTMENT	26.	
58	S C Y J DUBER	CANTED BULKHEAD L/H&R/H & SPLIT DECK ASSY	16.	
59	E B R	AFT FUSELAGE LOWER SKIN	22.	
60	B R	TAILBOOM VERTICAL SKIN	23.	
61	E G Z R	AFT FUSELAGE BULKHEAD FITTING UPPER L/H	24.	
62	E G Z R	AFT FUSELAGE BULKHEAD FITTING LOWER R/H	24.	
63	E G Z R	AFT FUSELAGE BULKHEAD FITTING UPPER R/H	24.	
NAME-PROFILER		RECORDS		

DRSTS-M FORM 1220
1 Mar 83

CARD COL.	PROFILE	INDICATOR NOMENCLATURE	ITEM REF.	[illegible]
64	E G Z R	AFT FUSELAGE BULKHEAD FITTING LOWER L/H	24.	AIRCRAFT SERIAL NO.
65	S C Y J D U R	MAIN BEAM AFT R/H	16.	
66	S C Y J D U R	AFT OUTBOARD FUEL CELL BULKHEAD R/H	16.	
67	S C Y J D U R	WORK DECK HONEYCOMB PANEL R/H	16.	
68	S C Y J D U R	UPPER AFT CABIN BULKHEAD R/H	16.	
69	S C Y J D U R	LOWER AFT CABIN BULKHEAD R/H	16.	
70	Y E A R	CARGO DOOR TRACKS R/H	15.	
71	Y B E R	DOOR POST R/H	14.	
72	S C Y J D U R	FWD PANEL MAIN FUEL CELL	16.	
73	C R	COAXIAL CABLES IN FWD HELL HOLE	26.	
74	S C Y J D U R	LOWER FUEL CELL H/C PANEL L/H	16.	
75	S C Y J D U R	LOWER FUEL CELL H/C PANEL R/H	16.	
76	S C Y J D U R	AFT CENTER HONEYCOMB PANEL	16.	
79		PROFILER'S IDENTIFICATION CODE	25.	

no disassembly of the aircraft. This is essential because of the thousands of aircraft that need to be evaluated and profiled annually. A more thorough evaluation of the aircraft could take several hours and require extensive disassesmbly of the aircraft and special equipment.

The ACE profiling of an aircraft by looking at its indicators can be analogized to a medical situation. A doctor will first check a person's vital signs (indicators) such as pulse, blood pressure, respiration, or reflexes to determine the person's overall health. If these are bad, the doctor may then send the person to the hospital for extensive tests or exploratory or corrective surgery (aircraft disassembly or depot overhaul).

In developing the list of indicators, the entire airframe is initially considered section by section and specific areas of deterioration identified. Then the impact of not repairing an area of deterioration is evaluated for potentially severe problems which could occur if not repaired. Four evaluation criteria are considered: aircraft safety, mission capability and readiness, the effect of accelerated deterioration, and general deterioration or fair wear and tear of an airframe. Accelerated deterioration refers to any expected increase in deterioration if a particular repair is not made on an aircraft. General deterioration refers to the state of general deterioration in which an aircraft could be expected to be in if it is allowed to remain in the field until the next evaluation cycle. Early and timely actions are more cost-effective than delayed actions where further deterioration can occur, even to the point where it may no longer be feasible to repair the aircraft. After identifying all the engineering, economic, and depot areas having an impact on the airframe condition, a list of indicators is made for each MDS aircraft type, utilizing all of the above factors for indicator selection.

Similarly, a list of condition codes is developed for each indicator to denote its range of faulty conditions or varying degree of severity of degradation, such as, dented, delaminated, corroded, etc., or good, fair or poor. Figure 2 shows examples of these two kinds of condition codes. Figure 3 displays all the current condition codes (ACE codes).

The number of indicators and condition codes varies by aircraft type ranging from 18 to 48 indicators and 1 to 8 condition codes. They are continually reviewed and updated by RCM&DESB engineers and published in AVSCOM Pamphlets 750-1.

2.1.2 Ranking of Indicators

The list of indicators are first ranked by RCM&DESB engineers for their degree of importance or criticality in the candidate selection process. This ranking is a subjective process which takes into consideration the four previously mentioned evaluation criteria of selecting indicators. Also considered are engineering and aeronautical importance, depot drivers, and the safety and economic benefits to be derived if the reported symptom and its causes or implications are eliminated by depot restoration. The criticality of indicator is governed by the extend of the impact on need for depot repair with respect to safety and cost if an indicator is faulty.

Figure 2

Types of Condition Codes

HOW BAD THE CONDITION OF THE INDICATOR IS

Indicator	Condition Codes
Paint Condition	C K L M

C - Deteriorated

K - Poor

L - Fair

M - Good

WHAT CAN GO WRONG WITH THE INDICATOR

Indicator	Condition Codes
Pylon Honeycomb Panel	S C Y J D U R

S - Delaminated

C - Deteriorated

Y - Temporary Repair

J - Punctured

D - Corroded

U - Dent

R - No Defect

Code letters are from AVSCOM Pam 750-1, Appendix B (as shown in Figure 5)

Figure 3

List of All Condition Codes
from AVSCOM Pam 750-1, Appendix B

TSARCOM PAM 750-1

APPENDIX B

LISTING OF ACE CODES

A - Worn Excessively
B - Buckled
C - Deteriorated
D - Corroded
E - Cracked
F - Misaligned
G - Loose Rivets
H - Major
I - Oxidized
J - Punctured
K - Poor
L - Fair
M - Good
N - Loose
P - Bent
Q - Minor
R - No Defect
S - Delaminated
T - Improper Hardware
U - Dent
X - Scratch
Y - Temporary Repair
Z - Bolts in Lieu of Rivets

Experienced engineers use a subjective ranking technique called the Emphasis Curve in which the criticality of each indicator is compared to that of each of the other indicators to show which is more critical. This process is done for the indicator lists of each of the aircraft MDS types. It is this comparative analysis of the condition indicators of each aircraft that provides the discrimination necessary to select aircraft in order of greatest need for return to the depot. It should be noted that the Emphasis Curve is not a curve, but rather a chart used for ranking items in ordinal position according to how much emphasis or relative importance is placed on them.

A sample Emphasis Curve for four indicators, shown in Figure 4, can be used to illustrate this process. The four indicators are first arbitrarily labeled A through D. A chart is then set up with pairs of these letters contained in boxes such that each letter is paired with each of the other letters once and only once. For each box, the items (indicators) corresponding to its two letters are then compared. In each of these comparisons the letter of the most critical item is circled. The number of times an item's letter is circled reveals its score for relative importance - the higher the score the more critical the item. In this example, A is not circled; so it has a score of 0. B is circled 3 times for a score of 3, C has a score of 1, and D a score of 2.

If there are any additions, changes and/or modifications of indicators, the whole process must be repeated and all indicators must be reranked.

Figure 4

Ranking of Indicators Utilizing the Emphasis Curve

INDICATORS

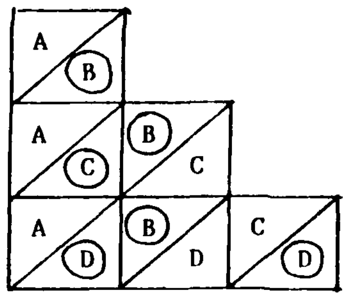
A. Paint Condition

B. Main Lift Beam

C. Pylon Honeycomb Panel

D. Upper Aft Bulkhead

EMPHASIS CURVE



RANKING OF INDICATORS

1. Main Lift Beam (B's score = 3)
2. Upper Aft Bulkhead (D's score = 2)
3. Pylon Honeycomb Panel (C's score = 1)
4. Paint Condition (A's score = 0)

2.1.3 Indicator Weight Assignment

Once the indicators are ranked, numerical weights can be assigned to quantify how much more critical each indicator is to the others. If the ranking of indicators is in the order of importance in terms of need for depot repair, then it logically follows that weighting would occur in the same order. Pareto's Principle of Maldistribution is employed for this task. Vilfredo Pareto (1848-1923), an Italian philosopher, observed that a small percentage of the total population in his native Italy accounted for a large percentage of the country's wealth. This observation has been generalized to "the significant few and the insignificant many" principle. A small portion of a group accounts for a significant portion of the group's value or effect, while a large portion or majority of the group will be of relatively insignificant value. Or, 80% of the value can be accounted for by 20% of the items, the "80/20" rule. This can be expressed mathematically as a curve of the form XY = A, where X is the group or indicators, Y is the value, ranking, or weight of group or indicators, and A determines the shape of the curve and how significant the few are.

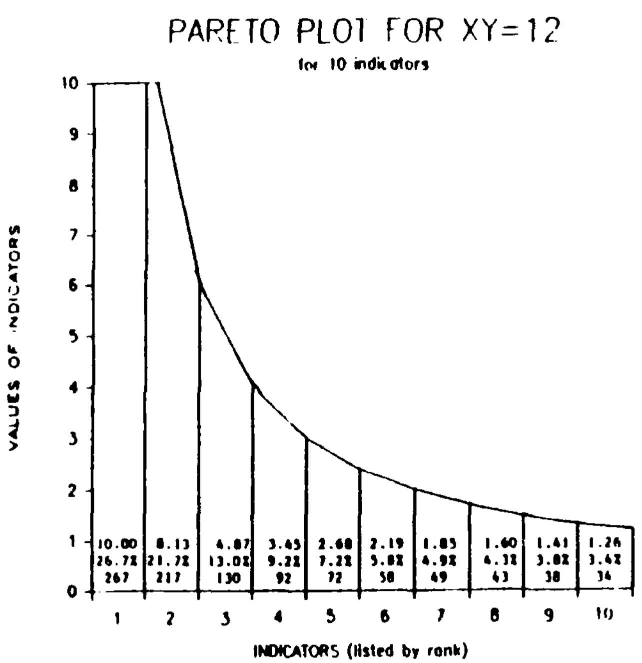
For the ACE program, the Pareto curve XY = A is truncated at the points X = number of indicators and Y = ranking in terms of number of indicators. Therefore, X has a range equal to the number of indicators. This form of the Pareto curve is symmetric. See Appendix A for more information on the Pareto Principle.

A Pareto curve is developed for each of the aircraft MDS types. The weight distribution for each indicator is determined by the ratio of the area under this curve at the indicator's ranking interval to the total area under the curve. By proper choice of the constant A, weighting of the indicators can be adjusted to achieve the desired relative weight distributions. This choice of A becomes a RCM&DESB management decision. It has usually been related to the desired weight percentage of the first designated number of indicators (e.g., the first 8 indicators determine 55% of the weight). Once the value of A is determined, the curve can be plotted and the weights for each indicator can be determined. Figure 5 illustrates this process for 10 indicators with A = 12 and A = 30.

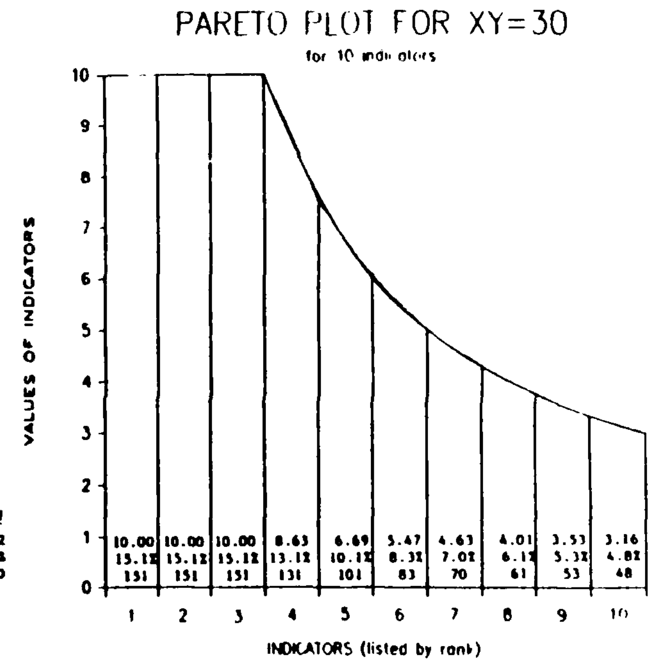
The weight for each indicator is proportional to the area under the curve in the indicator's interval. The interval's area under the curve can be found by integration. The sum of all the indicators' areas yields the total area under the curve. The percent area for each interval is the interval area divided by the total area multiplied by 100. Finally, the weight of each indicator is equal to the percent area for each indicator multiplied by ten. This puts the weights on a one thousand point total basis. In other words, if the weights of all the indicators are added, the sum will be one thousand. Figure 6 shows its output Pareto plot for the UH-1H/V with 46 indicators and A = 110 (note, the Y axis is on a smaller scale than ·ne X axis).

Figure 5

Pareto Curve Assignment of Weights



TOTAL		TOTAL
37.44	AREA UNDER CURVE	66.12
100%	% OF TOTAL AREA	100%
1000	WEIGHT	1000



THE THREE NUMBERS SHOWN IN EACH INTERVAL ARE:

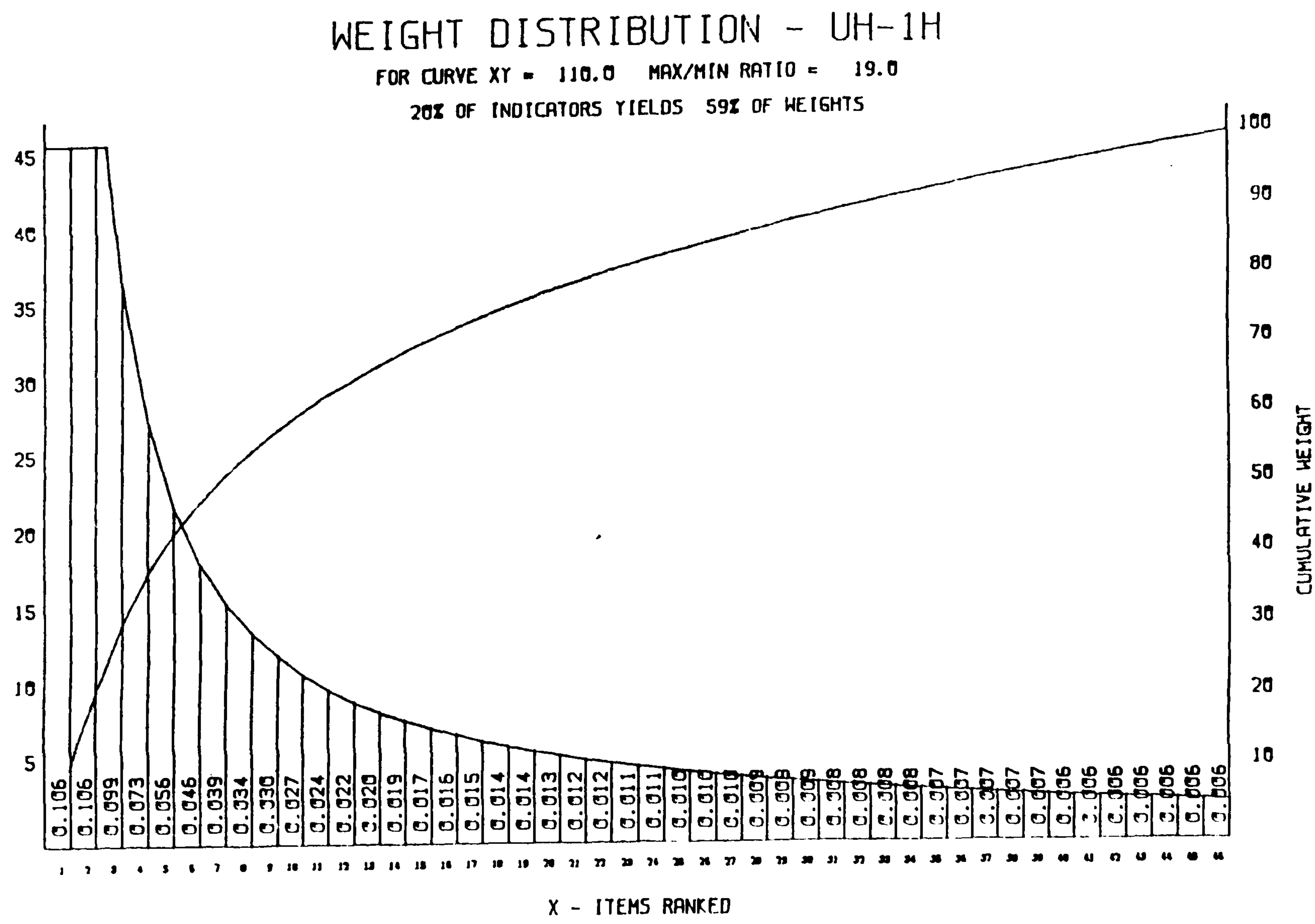
THE INTERVAL'S AREA UNDER THE CURVE, FOUND BY INTEGRATION.

THE INTERVAL'S PERCENT OF THE TOTAL AREA UNDER THE CURVE = (INTERVAL'S AREA) / (TOTAL AREA) x 100.

THE INDICATOR'S WEIGHT = (INTERVAL'S PERCENT) x 10.

Figure 6

Pareto Plot of Indicator Weight Distribution for the UH-1H/V



2.1.4 Condition Code Weight Assignment

Most of the ACE indicators have more than one condition code. Condition codes are first listed or ranked subjectively from worst to best condition for each indicator. This is based on the same considerations as the ranking of the indicators, although no formal Emphasis Curve is used. Weights are then assigned to these codes as a percentage of the weight allocated to the indicator. Weight assignments are currently made in accordance with an arbitrary valuation table, shown in Table I. This provides a uniform way of assigning the condition code weights (in terms of percentage of indicator weight) by following an averaging scheme. As shown in the table, weights are assigned so that the worst condition receives 100% of the indicator's weight and lesser conditions receive smaller percentages of the indicator's weight, such that the sum of these lesser weights is also 100% of the indicator's weight. The sum of these lesser weights could be less than 100% of the indicator's weight if their total importance were less than the worst case.

2.2 IMPLEMENTATION

2.2.1 ACE Team Evaluation and Profile

With the indicators, condition codes, and weights determined, the ACE teams can conduct the annual evaluation of each aircraft's condition and determine its profile. The teams evaluate the indicators of the basic airframe in an effort to detect the deterioration of the airframe, regardless of cause (progressive normal wear and tear, over-stressing,

Table 1

Condition Code Weight Distribution Valuation Table

NUMBER OF CODES	% OF TOTAL INDICATOR WEIGHT FOR CODES (Listed Worst to Best)					
	First Code	Second Code	Third Code	Fourth Code	Fifth Code	Sixth Code
6	100	50	20	15	10	5
5	100	50	25	15	10	
4	100	50	30	20		
3	100	60	40			
2	100	60				
1	100					

climatic conditions, etc.). An evaluation is needed annually because of non-progressive damage such as hard landings which can occur anytime, even just after an overhaul. Each ACE team is composed of 2 trained mechanics. There are currently 10 teams. These teams travel world-wide to annually profile each fielded aircraft in the Army's inventory. They perform the profiles during a 6 to 9 month period prior to the World-wide Aviation Logistics Conference (WALC) in the spring of each year. Prior to starting their profiling tours, they are trained for proper profiling techniques and instructions on AVSCOM Pam 750-1 (Reference 2) to assure consistent profiles by all team members.

The ACE teams profile the aircraft in accordance with AVSCOM Pam 750-1, published by the RCM&DESB for each aircraft MDS type. These guides are revised as necessary when new or additional information, such as indicator or condition code changes, is received from either the depot or the AVSCOM maintenance or engineering staff. The ACE teams evaluate each aircraft, indicator by indicator. Using simple visual or audio tools, such as flashlights, mirrors, or tappers, they check for any of the conceivable faulty conditions, for each indicator. The ACE team record their findings for the specific condition of each indicator on the ACE evaluation worksheet by circling the worst condition code for that indicator. These worst codes are then transferred to an ACE summary sheet. These sheets also require information on each aircraft, by serial or tail number, for special mission, aircraft type, command, and geographical location for future sorting of the data gathered.

The ACE teams do not assign weights or attempt to make any computations in the field. They only profile the aircraft and do not know the corresponding numerical indicator and condition code weights. The ACE team evaluation is only a data gathering effort. It is an evaluation and not an inspection. Profiling an aircraft does not require disassembly of the aircraft, only some minor depaneling to be done by the field unit for the ACE teams. The evaluation does not duplicate other required scheduled inspections so it can not be done by the field personnel. It must be done only by the properly trained ACE teams, using the appropriate guides and instructions for consistent profiling. The ACE profile does not require a complete technical inspection of the aircraft, nor does it in any way perform an inspection of the field unit's maintenance capability or performance. Any safety or flight discrepancies noted during the ACE profiling would be immediately brought to the attention of the owning unit for their action and not the ACE team's action.

2.2.2 Profile Index Determination

After the weights are set for each indicator by condition code, and the evaluation worksheets have been completed, then the aircraft are given a profile index (PI). The profile index of an aircraft is the summation of the weights of all the faulty indicators noted during evaluation.

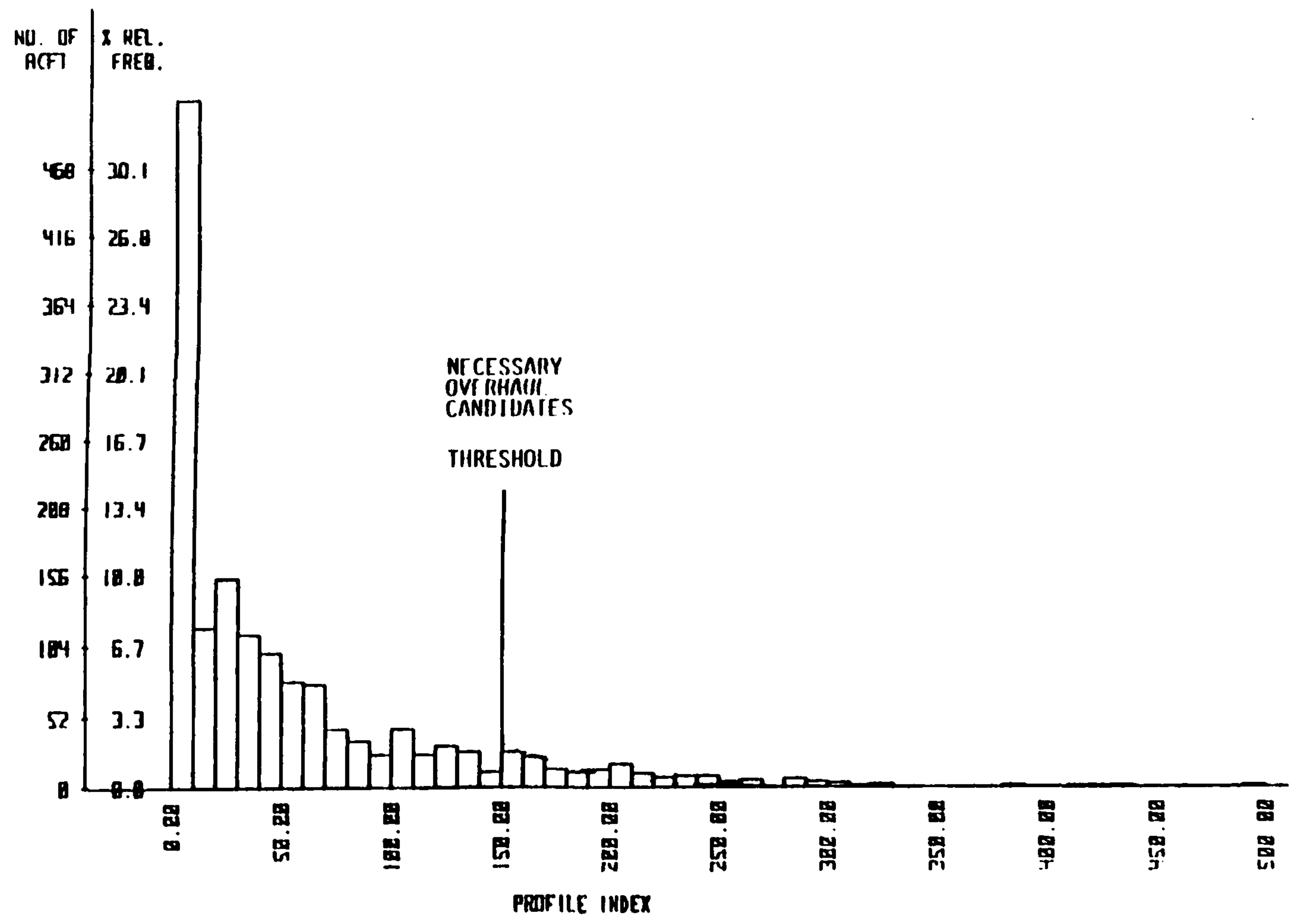
The PI provides a quantification or numerical ranking of the condition of each aircraft as compared to the other aircraft, and hence provides a means to rank the fleet. Thus, an aircraft with a PI of 450 would be in greater need of depot repair than one with a PI of only 200. Because of the Pareto Principle, an aircraft could have several faulty indicators and still have a lower PI than an aircraft with only one major faulty indicator. When all the aircraft have been evaluated and their condition expressed by the PI numerical value, they can be placed in descending or ascending order by PI, and a histogram of aircraft distribution can be obtained for each aircraft MDS type by command or georgraphical area, as shown in Figure 7.

2.2.3 Threshold Establishment and Candidate Identification

The profile index allows aircraft to be ranked and sorted by their need for depot repair. A criterion (or threshold) is then used to determine which aircraft are to be candidates for depot recall. The establishment of a threshold for the induction of aircraft into depot maintenance is a key area in the ACE program since it determines the operational acceptance level for the airframes of the active fleet. A threshold is expressed in terms of the profile index scale, and it can be thought of as the cutoff point in the priority-of-need listing by PI order (see Figure 7). Since each aircraft MDS type has different indicators, condition codes, and PI scales, a separate threshold is needed for each one. Once an aircraft's PI reaches or exceeds its threshold, it becomes a candidate for depot repair. Aircraft with PIs below this threshold limit do not require depot recall. While the ordered listing of the PIs will allow for selection of aircraft to be returned to depot on a worst-case-first basis, it is the threshold that cuts this selection process off when aircraft no longer

Figure 7

Profile Index Distribution and Threshold



need depot repair. A threshold should be the statistical point where it is more cost-effective to overhaul an aircraft than to continue to operate it. Also, the threshold should reflect the level where maintenance can no longer be handled by the field and must be done by depot. It should be noted that if an aircraft which has a PI exceeding its threshold is continued to be operated in the field instead of being returned to depot for repair, then potentially severe safety and maintenance problems can occur. Continued operation can result in loss of the aircraft or lives. When one of these aircraft is finally returned to the depot, high deferred maintenance costs can be incurred, or the aircraft's condition may have further deteriorated beyond feasible repair. Therefore the threshold is a powerful discriminator. The condition of the entire fleet as well as the money spent on depot repair can be affected by changing a threshold value.

Various different evaluation criteria can be used to establish a threshold. Such criteria can be safety, mission capability, availability or readiness, or economic consideration. A threshold can be established such that about 20 percent of a fleet will be returned for depot repair. This would be based on past depot maintenance experience and repair data. RCM&DESB is currently using criterion based on economic and depot requirements. Two separate thresholds are used for the entire fleet. Threshold of 150 for single-rotor aircraft and 200 for tandem and fixed-wing were used in the past ten years. Since October 1983, these thresholds were revised to be 200 for small and medium aircraft (OH-58, AH-1, OH-6 and UH-1) and 250 for large helicopter and fixed-wing aircraft (CH-47, CH-54, UH-60,, U-21 and OV-1). These current thresholds are based on an indepth audit of a partial sample of several hundred aircraft.

Aircraft in the sample are chosen to provide a representative range of aircraft MDS types and densities, commands, geographical areas, flight envelopes, environments, missions, and field facilities and expertise. Also chosen are aircraft whose PI is expected to fall near the threshold (based on previous years' data). Therefore the sample only considers aircraft in a small band about the threshold. The audit then fine-tunes and pinpoints the threshold within this band (or validates an old threshold if it is still correct).

2.2.4 Field Audit

For each of the selected sample aircraft, an indepth, several hour audit is performed in the field to attain its total maintenance burden (i.e., scheduled or backlogged maintenance). This is based on the needed maintenance manhours and material, levels of repair, and depot requirements such as tools, facilities, equipment, expertise, processes, and engineering not available in the aircraft's field unit. The aircraft's log books, as explained in TM 38-750 are reviewed for any unfinished maintenance and the needed hours are recorded. The aircraft is unbuckled (not disassembled) and a detailed inspection of the airframe, components, wiring, etc. is performed by experienced RCM&DESP engineers and mechanics. Based on their expertise, the hours needed to repair or replace any faults found are estimated, and any depot requirements are noted. Information on any hidden maintenance problems or any unusual aircraft characteristics are also obtained from the aircraft unit's Technical Inspector.

Based on all of the above sample information and on the depot criteria in TB 43-0002-3 and the Maintenance Allocation Charts (MACs), each aircraft is subjectively marked as either a depot (D) or field (F) candidate. After all the sample aircraft have been audited, the Ds and Fs are paired to the PIs for each aircraft, by serial number, and all are listed in descending PI order. Figure 8 provides an example of this process. Most of the Ds will lie in the upper range of the PIs, while the Fs fall at the lower range. Hopefully, a clear demarcation line arises, and the PI at this level is where the threshold is set.

This completes the selection of aircraft candidates for depot recall under the ACE program. It should be noted that many of the procedures of the ACE program are interrelated. Changes in one must be carefully considered to determine if a corresponding change in another is necessary. For instance, if the total number of indicators changes, then the indicators may have to be reranked. The Pareto curve would have to be replotted and the weights and PIs recalculated. The threshold may also need to be reevaluated since it is tied to the PI scale. Or, if the desired management decision in defining the Pareto shape A is changed, then the curve must be replotted and the weights and PIs recalculated. Again, the threshold must be reevaluated.

The ACE program identifies the aircraft candidates for depot repair based on the consideration of safety, mission and maintenance burden. It not only provides a priority-of-need list based on the condition of the aircraft by aircraft type and tail number, but also by geographical area and command. The engineering responsibility of the ACE program is completed at this stage. The actual selection of aircraft for depot repair is a maintenance and field responsibility.

Figure 8

Current Threshold Determination

ACE PROFILE

Aircraft Serial #	PI
1	120
2	350
⋮	
5	160
6	10
7	240
⋮	
25	225
⋮	
30	20
⋮	
50	140
⋮	
61	80
⋮	
64	205
⋮	
83	75
⋮	
96	190
⋮	
99	235
100	290

(Total A/C)

RCM&DESB ANALYSIS

Aircraft Serial #	Level of Repair
5	F
7	D
25	D
30	F
50	D
61	F
64	D
83	F
96	F
99	D

(Sample A/C)

COMPARISON
(Listed in Descending PI Order)

Aircraft Serial #	PI	Level of Repair
7	240	D
99	235	D
25	225	D
64	205	D
Threshold		
96	190	F
5	160	F
50	140	D
61	80	F
83	75	F
30	20	F

3.0 DATA ANALYSIS, REPORTING AND DOCUMENTATION SYSTEM (DARDS)

An effective implementation of the ACE program is predicated upon good understanding of the methodology and adequate management authority and support. Implementation is the last link in the entire ACE program to achieve the objective of identifying depot candidates for cost-effective repair. Assuming that management support and methodology are in place, the end result of implementation is to obtain reliable and consistent field data for analysis and depot candidate selection. The success of this effort is predicated upon efficient data handling and analysis, accurate airframe condition profiling, and the effectiveness of the ACE team.

Valuable data on the condition of the airframe are collected under this program. During the ACE team evaluation, other data are gathered for Modification Work Orders (MWOs), RCM, etc. Maintenance data are also recorded as repairs are performed on the items. This host of data provides an up-to-date and realistic assessment of depot repairs and the OCM program. They could be used to identify the design deficiencies of items. A list of the priority-of-need developed through ACE can serve not only to recall aircraft for depot overhaul, but also to provide the order of recall for aircraft modification programs. all of these lend themselves to the support of the Product Improvement Program (PIP), the Engineering Change Proposal (ECP), and other corrective actions. They will also allow an expedient, efficient and cost-effective OCM/ ACE operation, and provide a basis for realistic projection of budget and depot resource requirements.

A timely analysis and reporting of the above data will greatly enhance engineering and management decisions for up-to-date and realistic assessments of ACE and OCM. For the long terms, it will facilitate budget projections, ECP/PIP analysis, design deficiency evaluation, etc. A complete and automated data analysis and reporting capability for ACE will achieve the above.

3.1 DARDS Software Development

The intent of the DARDS software is to automate the entire ACE data analysis and reporting process. This will include the input of ACE field data, adjustment of indicators and condition codes, computation of weight assignments, printing and graphing of Pareto distribution, and data output reporting and documentation. One major feature of this software is that it should be fool-proof and user friendly, so that the data may not be accidentally altered due to human errors in operation of this software program. The software package dBASE III is employed as a tool to build this software structure.

3.2 Brief Description of dBASE III

dBASE III is the new database management standard for today's 16-bit microcomputers. Designed to take full advantage of recent computer advances, dBASE III makes the most of the power locked within the IBM PC, or IBM compatible microcomputer.

dBASE III deals in concepts, using an English-like vocabulary to help the user learn what a microcomputer can do and should do. It is called a relational database management system and uses powerful yet simple English-like commands that can be recognized immediately. With a single command, one can manipulate blocks of information and can add, insert, or delete information in the files. One can select all or part of a file and display it on the screen or print it as a report. The followings are highlights of dBASE III.

- o Relational database management system.
- o Full relational and programming features for interactive use and programmed applications development.
- o Easy to use with system mode, definitive help screens, English-like commands.
- o 128 fields and 4,000 characters per record.
- o New MEMO data type that allows records up to 500,000 charaters long.
- o One billion records per file.
- o 10 data files in use at the same time.
- o Ultra-fast multi-field sort.
- o Indexed files, ultra-fast find, etc.
- o Full Applications Development Language, with features such as procedures, parameter passing, and more.
- o Runs on IBM PC and compatibles.

3.3 DARDS Software

This section describes the implementation in terms of language, design and structure of code, hardware, input, output and storage.

3.3.1 Language

The dBASE III command language provides access to all of dBASE III's built-in high level data base management and screen commands. Unlike BASIC, the command language is conducive to writing well structured code. In terms of functionality, the dBASE III command language offers fewer mathematical functions than does BASIC. However, an analysis of the mathematical functions used in DARDS showed that, with one exception, all of the functions used in DARDS are available in dBASE III. The exception is the ABS( ) (absolute value) function, but the use of this function in one IF statement can be easily substituted.

Though the dBASE III command language is an interpreted and not a compiled language, it is expected that the high level (and fast) functions provided for handling indexed data files will lead to adequate performance for the DARDS software.

3.3.2 Design and Structure of Code

In the interest of insuring expandability and maintainability, structured design and programming techniques were used. The existing calculation portions of DARDS can be almost directly translated into dBASE III code. To speed the coding of major portions of new code, the Quickcode III program generator by Fox & Geller was used to generate screens and menu.

All coding activities can be greatly facilitated by a full screen program editor. Though a full screen prgram editor is included with dBASE III, it is somewhat limited in capability. Either editor can be called automatically by dBASE III when a MODIFY command is given if the appropriate command is added to the CONFIG.DB file of dBASE III. The CONFIG.DB file is explained in the dBASE III manual.

To assure proper functioning of dBASE III, the CONFIG.SYS files on the computer should contain the statements FILES=20 and BUFFERS=24. For more information on CONFIG.SYS files, see the chapter on "Configuring Your System" in the IBM DOS manual (chapter 4 of the DOS 2.10 manual).

3.3.3 Design

The design is described in five sections:

(1) File Structure

The file structure section lays out what files will form the heart of the enhanced ACEDARDS software. Under each file title are listed the data elements which will make up each file record. Underlined data elements indicate the primary key for retrieving records from each file. Compound keys are shown by two or more keys linked by an "&". a compound key is a way of using several data elements in combination to retrieve a unique record from a file.

(2) <u>Menu Formats</u>

The menu formats show how the computer screen will appear to users of the ACEDARDS software when they are asked to make menu selections. The first menu (the main menu) is what users will see when they initially start the system. Other menus will appear based on the selection made from the initial menu. For example, if a "1" for "Add Information" is selected from the main menu, the Add manu will be displayed.

(3) <u>Screen Formats</u>

The screen formats show how the computer screen will apear when entry of data is required. For example, the aircraft model screen will be displayed when users select to add, edit, or delete an aircraft model from the system.

(4) <u>Report Formats</u>

The report formats show how reports, such as the Pareto Weight Distribution for a particular aircraft model, will appear when displayed on the screen or printed on the printer.

(5) Program Design Language

The design of the dBASE III program is to control the display of screens, the entry of data, the production of reports, and the calculation of indicator weights and aircraft indices. Each module has as its title either the menu selection which activates it or the procedure name from the module that calls it. The design language describes the steps to be performed by each module in a "universal" language that is intended to be close to ordinary English.

3.3.4 Input

The user-friendly aspect of the ACEDARDS software is enhanced through menus and full screen input. To code the manu and screen designs, Quickcode III was used. Quickcode III, an add-on package for dBASE III, includes an easy to use screen builder utility and a utility for generating code to verify input.

3.3.5 Output

Quickcode III was also used to speed coding of these output reports. For graphics output of Pareto curves, dGRAPH III was used. dGRAPH III is a graphics utility from Fox & Geller that enables production of high resolution pie, bar, and line charts from dBASE III data. An added advantage of this package is that it would enable graphs of not only Pareto curves but of any other data stored in the ACE data base.

For transferring data files between St. Louis and Corpus Christi, which may be a future requirement, the SmartCom II software may be included with the Hayes 1200B modem. SmartCom II would enable setup of automatic dial up and data transfer procedures in either direction.

3.3.6 Storage

The ACE data are stored in well designed indexed dBASE III files. The following is an example of a data structure for the ACEDARDS software.

(1) Annual evaluation data files:
   (a) AVSCOM data file
   (b) Fleet data file
   (c) Aircraft type evaluation data file
   (d) Individual aircraft evaluation data file

(2) Aircraft type indicator data files:
   (a) Indicator data file
   (b) Condition code data file

Indexing on all fields is the key to enhance performance from using dBASE III. Indexing works by maintaining a set of pointers that enables direct access to records without sorting in the same way that a card catalog in a library enables direct access to books without searching through all of the shelves. The dBASE III manual provides additional information on indexing and on settng up indexed files.

Once the ACE data is stored in dBASE III files, one will be able to take advantage of dBASE III's extensive ad hoc query capability. Queries of nearly unlimited complexity can be made interacctively in dBASE III, and the results displayed on the screen or printed can be easily formatted in the desired reports.

If future requirements for functionality and performance ever exceed the capabilities of the dBASE III command language, dBASE III files can be interfdaced to both BASIC and Lattice C programs. Quickcode III provides the ability to transfer data from dBASE III to BASIC, and dB-C from Lattice Inc. provides access to (and even creation of) dBASE III files from Lattice C programs. It is reassuring that future expansion of the DARDS software is not limited by the capability of the dBASE III command language.

3.4 HARDWARE

It is recommended that the IBM PC be equipped with expanded memory and a clock/calendar. According to the Ashton-Tate, dBASE III requires a minimum of 256K of RAM memory. Typically, minimum memory requirements quoted by vendors are on the low side to avoid excluding any major portion of the PC market. Therefore, dBASE III should not be operated on a regular basis with 256K. In fact, the computer would need approximately 608K of memory to have dBASE III, Quickcode III or dFORMAT, dGRAPH III, and Volkswriter in memory at one time. While it may never be essential to have all of these programs in RAM at once, one can easily envision situations where the computer would need significantly more than its current 256K of memory. When future requirements for telecommunication are considered, the need for expanded memory in the computer becomes even more apparent. To assure accurate dating of data files for version control, we recommend the addition of a clock calendar to the computer. In order to expand the memory and add the clock/calendar in only one expansion slot, we recommend that the computer be equipped with the AST SixPakPlus multifunction board. This board combines a reliable clock/calendar, a serial port, a parallel port, and up to 384K of memory on a single board. Given the low cost of memory compared with the labor cost of later expansion, we recommend that the SixPakPlus boards be initially purchased with the full 384K already installed. Installation of these boards will bring the total memory of both computers up to 640K.

To assure that data files are accurately and consistently dated, the command for loading the clock/calendar data (ASTCLOCK/R) should be placed in the AUTOEXEC.BAT files of the compouter. For more information on AUTOEXEC.BAT files, see the "Automatic Program Execution" section of the IBM DOS manual (pages 1-27 of the DOS 2.10 manual).

Telecommunication of data files between St. Louis and Corpus Christi may be a long term requirement that will also entail an addition to the hardware. To meet this requirement, we recommend that a Hayes 1200B modem board eventually be added to the computer. The Hayes 1200 modem is the industry standard modem for IBM PC computers. It is also reliable, relatively inexpensive, and comes complete with SmartCom II, an excellent telecommunications software package.

4.0 ACEDARDS COMPUTER PROGRAM: USER'S GUIDE

4.1 Introduction

The ACEDARDS Program provides the basic calculations for the Army's ACE program. ACEDARDS is a data base system using dBASE III language. It calculates the indicator and condition code weights and the profile indices. It also calculates cost and composite indices, if appropriate cost data is entered (this is not currently being done). Inputs include information from the Appendices of AVSCOM PAM 750-1, especially Appendix A, and from the ACE ranking sheets and percent weight table (for indicator weight distributions to condition codes). Outputs include Pareto weights for indicators and the plot of the Pareto curve, condition code weights, and indices sorted by aircraft serial number, profile index, cost index, or composite index for each aircraft type for all commands or each command. Input information is provided in Appendix A. The mathematics of the Pareto curve are provided in Appendix B. The CACI report of January 1985 on the ACE Program provides detailed information on the ACE program and its methodologies for weight and indices calculations.

ACEDARDS is user friendly. It is an interactive program which displays information on the CRT screen and prompts the user for input. It displays menus for the user to select a desired operation such as add, edit, delete, print, etc., with resulting screens to enter or change appropriate information. The input screens are used to build and edit all of the data files.

The program is "foolproof" in that is attempts to keep the user from making mistakes such as incomplete information, invalid entries, etc. Appropriate prompts and error messages are displayed for the user. The program always keeps the files up-to-date, recalculates all weights after any indicator or condition code changes, recalculates all indices after any evaluation data entries, etc. Because of this structure, ACEDARDS is a self-teaching program.

4.2 Procedure

(1) To initialize the program, enter ACEDARDS from any directory (at the DOS prompt) or enter DO ACEDARDS from dBASE III.

(2) As menus appear, enter desired selection number or letter. An appropriate screen will then appear displaying requested information on the screen in the bracketed, reverse video (black letters on white background) blocks. Answer each block of requested information where the cursor is located, by using the standard edit keys of the keyboard (return/↵, arrows, Ins, Del, etc.) to enter the desired response or data. If all of a block is filled in, the cursor automatically goes to the next block; otherwise press the return key or arrow key to move to the next block of requested information.

(3) Corrections can be made to the current screen for most items in reverse video by using the edit keys. I.e., the user can go back to previous blocks in reverse video to correct them. Suggest the user proof all of the screen before moving on to next screen. Previously entered information not in reverse video can not be edited (the user must go back to the main menu and select the Edit option to do this). In particular,

check the Evaluation Profile Aircraft Information Screen (called from option 5 of the main menu) before moving on, as there is no edit for this screen and any invalid data must be completely reentered.

(4) If an error message appears, it usually ask the user to press a key to continue. This must be done to continue the program and move on, and before retrying entry of new data. If the dBASE error message to "Terminate command file? (Y/N)" appears, enter Y and then type Quit to exit dBASE and ACEDARDS to reenter the program.

(5) Most screens return to the same screen or previous menu upon completion of the data input and any resulting data processing. This allows the user to repeat the screen for another set of data. If something different is desired, type a blank (by hitting the space bar) and press the return key in the designated block or blocks until the screen clears, and a new menu or screen appears.

(6) When a screen appears, some blocks may have default data in them showing the first item or data used just previously, as the user may want to continue on with more input for this item. If this default is desired, press the return key to accept it, otherwise type over the default with desired new data, as for a new entry.

(7) The user must enter data (or blanks) for all requested information before program will go to next screen or menu. For example, if in adding an aircraft model to the system, the number of indicators is entered as 44, the user must go through all 44 indicators screens (and corresponding condition code screens) before returning to menu. The user can't quit in the middle - this is part of the built-in error checking to prevent incomplete data.

(8) Upon completion of entry of requested information, the program usually performs some calculations or processes the data. Usually a message appears at the top of the screen to tell the user this is happening. Wait until the drive light stop blinking and the screen reappears or the cursor returns to an input block before entering new data or options.

(9) Once the user is familiar with the model screens and the requested information, information can be typed ahead of block/cursor prompts to speed input entry.

(10) The Display/Print Graph of Pareto Weighting Curve option takes the program out of dBASE III, and returns the user to the ACEDARDS main menu. Type D or P to display or print the graph and press the return key. When the display or print is completed, type M and the return key to return to the ACEDARDS main menu.

4.3 Specifics

(1) In using Add an Aircraft Model to the System or Add Indicators to an Aircraft, this program is not limited to 50 indicators or 80 card columns (as the COBOL program, which requires indicators in card columns 31 to 80). However, the number of condition codes per indicator is limited to 10 (8 is currently the maximum being used, and the percent weight table has been established for up to 8 condition codes).

(2) In adding or deleting indicators (which can only be done from the add or delete options and not the edit option) the indicator weights are recalculated for the new number of indicators. These recalculations are based on the existing methodology option selected in the Pareto Weighting

Curve Calculation Option (A,M,F,S) for calculating the Pareto "A" parameter of XY=A in the Aircraft Model Screen. If the A (for "A" parameter) option was used, the user may want to edit the aircraft model information and change the value of "A" parameter. The Pareto A parameter should be dependent on the number of indicators. The other options for the Pareto Weighting Curve Calculation are a function of the number of indicators, and the program automatically recalculates the "A" parameter accordingly for these options. However, the A option calculation is independent of the number of indicators, so the "A" parameter should be manually changed, if desired, for this option.

(3) When adding an aircraft model to the system or adding an indicator to an aircraft model, be careful with the number of condition codes for each indicator. In entering the allowable condition codes for each indicator, only include defective codes - do not include M (good) or R (no defect). If an indicator shows condition codes C K L M on Appendix A of AVSCOM PAM 750-1, this indicator has 3 defective conditions and only C, K, and L should be entered into the ACEDARDS program screen.

(4) In editing an aircraft model, only the variables corresponding to the selected Pareto Weighting Curve Calculation Option are necessary to edit. The other variables will be recalculated by the program, based on the new calculation option information.

(5) In the display or print of the indicator weights by condition codes, the indicator names are truncated to 25 letters, although the program allows 45 letters of input from the profile evaluation sheet of Appendix A of AVSCOM PAM 750-1. The user may want to make sure the first 25 letters of the name are unique.

(6) In entering the evaluation data from the profile sheet (Appendix A of AVSCOM PAM 750-1), for any circled or X'd Ms and Rs enter a blank (if M or R is entered, an error message will appear). For any aircraft with no defect, i.e., with nothing circled, M circled, or R circled, you can either omit that aircraft entirely (not recommended) or enter the aircraft serial number and a blank for each card column.

(7) The profile index, cost index, and composite index are not updated for each aircraft until evaluation data is entered (from option 5 of the main menu). If only indicators and condition codes are changed, the indices are not recalculated, since the aircraft would have to be reprofiled if these changes were made. When the indices are recalculated, only the most recent evaluation results are used; old indices are left unchanged.

(8) Several data bases in the ACEDARDS program can only be edited (i.e., there is no add or delete option) because they are expected to be changed very infrequently. These include the Condition Code Name, Major Command Name, and Percent Weight Table files. To add or delete information (records) to or from these files, dBASE III commands can be used outside the ACEDARDS program.

4.4 General

(1) Many of the variables in the program have been integerized or rounded to whole numbers in the displays and printouts. These include the Pareto "A" parameter, the number of indicators, the indicator and condition code weights, and the profile, cost, and composite indices.

In the Pareto Weighting Curve Calculation Option, if the "A" parameter is calculated, the other parameters are recalculated, based on the inter on the intergerized "A" value. Likewise, if indicators of the significant few or flat portion are input as percents (decimals), then the resulting number of indicators is intergerized, and the percents are recalculated.

As with any computer program, roundoff errors occur. For instance, when the indicator weights are integerized, they may no longer add up to exactly 1000, but may be 997 or 1002, etc. Likewise, in distributing the indicator weight to its condition codes, the sum of the condition code weights may not add exactly to the indicator's weight. Also, for any condition code with a weight less than .5, the program rounds this to 1 instead of 0, so that all faulty conditions have a positive (non-zero) weight.

(2) For all items that are deleted in the ACEDARDS program, the corresponding records in the appropriate database file are only marked for deletion. The files are not packed. This means that the deleted data can be recalled through a dBASE III command, if desired. Or, it can be packed through a dBASE III command to completely remove the data from the files. The user may periodically want to pack the files and reindex them in order to clear up the files and free space on the hard disk.

(3) As new evaluation profile data, with new date of ACE, is entered into the system, the old data still remains in the files. The user may want to periodically copy some of the old data into backup files on diskettes to free up the hard disk.

4.5 Enhancements

Other data analyses can be readily generated using dBASE III's vast search and sort/index capabilities on the database files created by the ACEDARDS program. Also dGRAPH III can graph anything from these database files.

Because of its modular programming structure, the ACEDARDS dBASE III program is easy to modify and enhance with new data analyses and reports.

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c.	C1-TSARCOMP 750-1(3)	AH-1/TH-1	Jul 1982
d.	C1-TSARCOMP 750-1(4)	UH-1B/C/M	Feb 1983
e.	C1-TSARCOMP 750-1(5)	CH-47A/B/C/D	Jul 1979
f.	TSARCOMP 750-1(6)	T-42	Feb 1979
g.	C1-TSARCOMP 750-1(7)	OH-6A	Mar 1983
h.	TSARCOMP 750-1(8)	OV-1	Feb 1978
i.	C1-TSARCOMP 750-1(9)	U-21	May 1983
j.	C1-TSARCOMP 750-1(10)	CH-54A/B	Jan 1978
k.	TSARCOMP 750-1(14)	UH-60A	May 1983

APPENDIX A

INPUT INFORMATION

APPENDIX A INPUT INFORMATION

A.1 Introduction

This appendix contains information on input data needed to use the ACEDARDS program. Input screens of the program are shown in Figures A-1 to A-13, with the sources of the requested data provided below each screen. Many of these sources refer to Appendices A to G, excluding D, of AVSCOM PAM 750-1, shown here in Figures A-14 to A-19. In particular, Appendix A of the PAM (Figure A-14) is a main source, as much of the information on this sheet is obtained from the other 5 appendices of the PAM. Another chief source of input data is the ranking sheets for the indicator and condition codes weights shown in Figure A-20. A third source is the percent weight table used for indicator weight distributions to condition codes, shown in Figure A-21.

A.2 Input Screens for Aircraft Indicator and Condition Code Data

The input screens of Figures A-1 to A-6 are used for entering the aircraft indicator and condition code data needed to calculate the indicator weights from the Pareto curve and distribute them to the condition codes using the percent weight table. The screens shown in Figures A-1 to A-6 are for the add option. Similar screens are used for the edit and delete options, with many of the blocks of information filled in by the program with existing data, as defaults to be edited or deleted by the user.

A.3 Edit Screens for Lookup Tables

The screens of Figures A-7 to A-10 are used for editing data in lookup tables that match code letters to names or provide basis percentages or rates. These screens can only be edited (there are no add or delete options for these) as they are expected to be changed very infrequently.

A.4 Entry Screens for Profile Evaluation Data

The screens of Figures A-11 to A-12 are used to enter the profile evaluation data obtained from the annual profile of each of the Army aircraft in the field. These screens are strictly for adding information, and there is no edit or delete. Incorrect data can be changed by re-entering the complete screen of data. The screen of Figure A-13 is to edit the profile threshold. This can also be done by editing the aircraft model screen of Figure A-1, and is provided with the evaluation data screens as a convenience.

Figure A-1
Aircraft Model Input Screen

```
ACE DARDS
Aircraft Model Screen
--------------------------------------------------------------------------
Enter model code for new aircraft model. Enter blank aircraft
model code to return to add menu.

Aircraft Model Code    [ ]              Aircraft Model

Number of Indicators                    Profile Index Threshold

Pareto Weighting Curve Calculation Option ( A, M, F, or S ) ......

   (A) "A" Parameter ( XY = A ) ............................

   (M) Max/Min Ratio ( decimal )........................

   (F) Flat Portion of Curve ( number of indicators ) ....

   (S) Significant Few:
         Number or Percent of Indicators ( decimal ) ....
         That Determine Percent of Weight ( decimal ) ...
```

Data Item	Source
Aircraft Model Code	AVSCOM PAM 750-1, Appendix A or C
Aircraft Model (Name)	AVSCOM PAM 750-1, Appendix A or C
Number of Indicators	AVSCOM PAM 750-1, Appendix A (count from card column 31 to end of indicators) or Ranking Sheet (count number of indicators)
Profile Index Threshold	ACE data
Pareto Weighting Curve Calculation Option	ACE data or user's choice
(A) "A" Parameter	ACE data or user's choice, only for chosen option
(M) Max/Min Ratio	
(F) Flat Portion of Curve	
(S) Significant Few:	
# or % of Indicators	ACE data or user's choice
That Determine % Wt	ACE data or user's choice, only if S chosen

Figure A-2
Multiple Indicators Input Screen

```
ACE DARDS
Multiple Indicators Screen

Enter card column, name, and number of condition codes for
each indicator in rank order.

Aircraft Model Code                 Aircraft Model

                          Indicator
Rank   CardCol                      Name                       #CondCodes

 1      [31]     [                                         ]      [  ]
 2
 .
 .
 .
```

Data Item	Source
Aircraft Model Code	Program provided
Aircraft Model (Name)	Program provided
Indicator Rank	Program provided
Indicator Card Column	Ranking Sheet
Indicator Name	AVSCOM PAM 750-1, Appendix A or Ranking Sheet
Indicator # of Condition Codes	AVSCOM PAM 750-1, Appendix A or Ranking Sheet

Figure A-3
Multiple Condition Codes Input Screen

```
                              ACE DARDS
                    Multiple Condition Codes Screen
 -------------------------------------------------------------------------
     Enter condition code letter, repair manhours, and repair
     material costs for each condition code in rank order.

   Aircraft Model Code                         Indicator Card Column
   Indicator Name

   --------------------------- Condition Code ---------------------------
   Rank    Letter    Avg Repair Manhours     Avg Repair Material Costs
   ----   --------------------------------------------------------------
    1      [ ]        [          ]                [          ]
    .
    .
    .
```

Data Item	Source
Aircraft Model Code	Program provided
Indicator Card column	Program provided
Indicator Name	Program provided
Condition Code Rank	Program provided
Condition Code Letter	Ranking Sheet
Condition Code Avg Repair Manhours	CCAD data
Condition Code Avg Repair Material Costs	CCAD data

Figure A-4
Indicator Input Screen

```
                              ACE DARDS

                           Indicator Screen
 ---------------------------------------------------------------------

        Enter aircraft model code and indicator card column
        for new indicator.  Enter blank indicator card column
        to return to add menu.

   Aircraft Model Code [ ]                Aircraft Model


   Indicator Card Column ..................................... [   ]

   Indicator Rank .........................................

   Indicator Name ...

   Number of Condition Codes .................................
```

Data Item	Source
Aircraft Model Code	User's choice
Aircraft Model (Name)	Program provided
Indicator Card Column	User's choice from (revised) Ranking Sheet or AVSCOM PAM 750-1, Appendix A
Indicator Rank	Ranking Sheet
Indicator Name	Ranking Sheet or AVSCOM PAM 750-1, Appendix A
Number of Condition Codes	Ranking Sheet or AVSCOM PAM 750-1, Appendix A

Figure A-5
Condition Code Input Screen

```
ACE DARDS

Condition Code Screen
--------------------------------------------------------------------
Enter aircraft model code, indicator card column, and condition
code letter for new condition code.  Enter blank condition code
letter to return to add menu.

Aircraft Model Code [ ]            Aircraft Model

Indicator Card Column [  ]

Indicator Name

          Condition Code Letter ................. [ ]

          Condition Code Rank ..................

          Avg Repair Manhours ............

          Avg Repair Material Costs .....
```

Data Item	Source
Aircraft Model Code	User's choice
Aircraft Model (Name)	Program provided
Indicator Card Column	User's choice
Indicator Name	Program provided
Condition Code Letter	User's choice from (revised) Ranking Sheet or AVSCOM PAM 750-1, Appendix A
Condition Code Rank	Ranking Sheet
Avg Repair Manhours	CCAD data
Avg Repair Material Costs	CCAD data

Figure A-6
Transportation Cost Input Screen

```
ACE DARDS

Transportation Cost Screen
-------------------------------------------------------------
Enter aircraft model code and major command code for
transportation cost to be added.  Enter blank command
code to return to add menu.

Aircraft Model Code [ ]          Aircraft Model

Major Command Code  [ ]          Major Command

Transportation Cost per Aircraft ................ $
```

Data Item	Source
Aircraft Model Code	User's choice from AVSCOM PAM 750-1, Appendix C
Aircraft Model (Name)	Program provided
Major Command Code	User's choice from AVSCOM PAM 750-1, Appendix E
Major Command (Name)	Program provided
Transportation Cost/Acft	Directorate for Maintenance data

Figure A-7
Condition Code Name Edit Screen

```
                              ACE DARDS

                     Condition Code Name Screen
-----------------------------------------------------------------------

        Enter the condition code letter for the condition code
        name to be edited.  Enter a blank letter to return
        to the edit menu.

          Condition Code Letter .......................... [ ]

          Condition Code Name ....
```

Data_Item	Source
Condition Code Letter	User's choice from (revised) AVSCOM PAM 750-1, Appendix B
Condition Code Name	AVSCOM PAM 750-1, Appendix B

Figure A-8
Percent Weight Table Edit Screen

```
ACE DARDS

Percent Weight Table Screen

--------------------------------------------------------------------------

Enter number of condition codes and condition code rank for
percent weight to be edited.  Enter blank condition code rank
to return to the edit menu.

     Number of condition codes ................ [  ]

     Condition code rank ...................... [  ]

     Portion of the total indicator weight
          ( decimal percent ) ................
```

Data Item	Source
Number of Condition Codes	User's choice from (revised) Percent Weight Table
Condition Code Rank	(Condition code with rank of 1 is always 100% (1.00) of indicator weight; this can not
Portion of Indicator Wt	be changed in the program.)

Figure A-9
Major Command Edit Screen

```
                              A&E DARDS

                        Major Command Screen
---------------------------------------------------------------------

          Enter the major command code for the major command to be
          edited.  Enter a blank code to return to the edit menu.


              Major Command Code .......................... [ ]

              Major Command Name ............
```

Data Item	Source
Major Command Code	User's choice from (revised) AVSCOM PAM 750-1, Appendix E
Major Command Name	AVSCOM PAM 750-1, Appendix E

Figure A-10
Depot Burdened Hourly Rate Edit Screen

```
                              ACE DARDS

                  Depot Burdened Hourly Rate Screen
 ----------------------------------------------------------------------

         Edit the depot burdened hourly rate with the keyboard



     Average Depot Burdened Hourly Rate .............. $ [       ] / Hr
```

Data Item	Source
Avg Depot Hourly Rate	CCAD Data

Figure A-11
Evaluation Profile Aircraft Information Entry Screen

```
ACE DARDS

Evaluation Profile Aircraft Information Screen
---------------------------------------------------------------------------

    Enter aircraft model code from the evaluation sheet.
    Enter blank model code to return to main menu.

  Aircraft Model Code [ ]            Aircraft Model

          Serial Number ......................
          Special Mission Code ......................
          Major Command Code ......................
          Geographical Location Code ...............
          Julian Date of ACE ....................
          Aircraft New or Overhauled ................
          Overhauled by ............................
          Aircraft Hours at Time of Overhaul ....
          Julian Date of Overhaul ................
          Total Hours on Aircraft ...............
```

Data Item	Source
Aircraft Model Code	AVSCOM PAM 750-1, Appendix A, Card Col 01
Aircraft Model (Name)	Program provided
Serial Number	AVSCOM PAM 750-1, Appendix A, Card Col 02-08
Special Mission Code	AVSCOM PAM 750-1, Appendix A, Card Col 09
Major Command Code	AVSCOM PAM 750-1, Appendix A, Card Col 10
Geo Location Code	AVSCOM PAM 750-1, Appendix A, Card Col 11-12
Julian Date of ACE	AVSCOM PAM 750-1, Appendix A, Card Col 13-16
Aircraft New or Overhaul	AVSCOM PAM 750-1, Appendix A, Card Col 17
Overhauled by	AVSCOM PAM 750-1, Appendix A, Card Col 18
Aircraft Hrs at Overhaul	AVSCOM PAM 750-1, Appendix A, Card Col 19-22
Julian Date of Overhaul	AVSCOM PAM 750-1, Appendix A, Card Col 23-26
Total Hours on Aircraft	AVSCOM PAM 750-1, Appendix A, Card Col 27-30

Figure A-12
Evaluation Profile Indicator Entry Screen

```
                         ACE DARES
            Evaluation Profile Indicator Screen
-----------------------------------------------------------------
      Enter condition code letter for each indicator from evaluation
      sheet.

  Serial Number                          Julian Date of ACE

                    Indicator
          Card Column               Condition Code Profile
          ----------------------------------------------
              11                            [ ]
              12
               .
               .
               .
```

Data Item	Source
Serial Number	Program provided
Julian Date of ACE	Program provided
Indicator Card Column	Program provided
Indicator Condition Code Profile (Letter)	AVSCOM PAM 750-1, Appendix A, Circled or X'd letter for corresponding card column

Figure A-13
Profile Index Threshold Edit Screen

```
---------------------------------------------------------------
|                                                             |
|                         ACE DARDS                           |
|                                                             |
|              Profile Index Threshold Screen                 |
|                                                             |
|-------------------------------------------------------------|
|                                                             |
|         Enter aircraft model code for Profile Index threshold
|         to be changed.  Enter blank model code to return to |
|         indices menu.                                       |
|                                                             |
|           Aircraft Model Code ........................ [ ]  |
|                                                             |
|                                                             |
|           Aircraft Model ....................               |
|                                                             |
|                                                             |
|           Profile Index Threshold ....................      |
|                                                             |
|                                                             |
---------------------------------------------------------------
```

Data Item	Source
Aircraft Model Code	User's choice
Aircraft Model (Name)	Program provided
Profile Index Threshold	ACE data

Figure A-14

Appendix A of AVSCOM PAM 750-1

APPENDIX A

AIRFRAME CONDITION EVALUATION (ACE) OH-6A TSARCOM 750-1(7)	MASTER	EAM	UNIT	AREA	LOCATION

CARD COL	PROFILE	INDICATOR NOMENCLATURE	ITEM	
01	M	TYPE/MODEL/SERIES	1.	AIRCRAFT SERIAL NO
02-08		SERIAL NUMBER	2.	
09		SPECIAL MISSION	3.	
10		MAJOR COMMAND	4.	
11-12		GEOGRAPHICAL LOCATION OF A/C	5.	
13-16		JULIAN DATE OF ACE	6.	
17	NO	A/C NEW OR OVERHAULED	7.	
18	C N S P K	O/H BY	8.	
19-22		A/C HOURS AT TIME OF OVERHAUL	9.	
23-26		JULIAN DATE OF OVERHAUL	10.	
27-30		TOTAL HOURS ON A/C	11.	
31	C K L M	OVERHAUL CONDITIONS	12.	
32	C K L M	PAINT CONDITION	13.	
33	C E X R	COCKPIT TRANSPARENCIES	14.	
34	D G Y R	BATTERY COMPARTMENT	15.	
35	E G Y J R	PASSENGER COMPARTMENT FLOOR	16.	
36	E F Y R	CABIN DOORS L & R	17.	ACE FY
37	E G B Y R	PASSENGER COMPART. BULKHEAD & VERTICAL WEBS	18.	
38	E G B Y R	FWD LANDING GEAR/DRAG STRUT ATTACH AREA	19.	
39	E B G D Y R	FORWARD KEEL BEAM	20.	
40	E G B Y R	AFT LANDING GEAR/DRAG STRUT ATTACH FIG.	21.	
41	E G Z Y R	UPPER EXTERNAL LONGERON R/H	22.	
42	E G Z Y R	UPPER EXTERNAL LONGERON L/H	22.	
43	E G B D Y R	AFT FUSELAGE SKIN, EXTERIOR & INTERIOR	23.	
44	E B J Y R	FIREWALL F.S. 124	24.	
45	E G B Y R	AFT RING BULKHEAD	25.	
46	E G Z Y R	TAILBOOM ATTACH FITTINGS	26.	
47	E X U R	ROTOR HEAD ASSY MTG PLATFORM BEAMS L/R & Floor	27.	
48	E G B Y R	CONTROL COLUMN	28	
79		PROFILERS IDENTIFICATION CODE	29.	

NAME PROFILER	RECORDS

DRSTS-M FORM 1226
1 Mar 83

Figure A-15

Appendix B of AVSCOM PAM 750-1

APPENDIX B

LISTING OF ACE CODES

A - Worn Excessively
B - Buckled
C - Deteriorated
D - Corroded
E - Cracked
F - Misaligned
G - Loose Rivets
H - Major
I - Oxidized
J - Punctured
K - Poor
L - Fair
M - Good
N - Loose
P - Bent
Q - Minor
R - No Defect
S - Delaminated
T - Improper Hardware
U - Dent
X - Scratch
Y - Temporary Repair
Z - Bolts in lieu of Rivets

LISTING OF SPECIAL MISSION CODES

2 - Reserved
3 - Non Standard Paint
4 - VIP/AC
5 - Medivac Equipped
6 - Fire Equipped
7 - Electronic equipped
8 - Weapon Equipped
0 - Standard Configuration

Figure A-16

Appendix C of AVSCOM PAM 750-1

C1, TSARCOM PAM 750-1(7)

APPENDIX C
AIRCRAFT CODES

A. - A/TH-1G

B. - AH-1S

C. - AH-64A

D. - Ch-47A

E. - CH-47B

F. - CH-47C

G. - CH-47D

H. - CH-54A

I. - CH-54B

J. - OH-58A

K. - OH-58C

L. - OH-58D

M. - OH-6A

N. - OV-1B

O. - OV-1C

P. - OV-1D

Q. - RV-1D

R. - U-21A/F/G

S. - RU-21A/B/C/H

T. - UH-1B

U. - UH-1C

V. - UH-1H

W. - UH-1M

X. - UH-1V

Y. - UH-60A

Figure A-17

Appendix E of AVSCOM PAM 750-1

APPENDIX E

COMMAND CODES

A - DARCOM

B - Bailed

C - TSARCOM (NICP)

D - DCSPER

E - USAREUR

F - FORSCOM

G - Blank

H - Blank

J - JAPAN

K - MLDFCMD (Kawjalein)

L - Loaned

M - MDW

N - US Army National Guard

P - WESTCOM

R - US Army Reserve

S - Stored

T - TRADOC

U - Eighth US Army Korea

V - USARSO

W - Other: REDCOM, TSC, HEALTH SVC

X - State Department

Figure A-18

Appendix F of AVSCOM PAM 750-1

C1, TSARCOM PAM 750-1(7)

APPENDIX F

GEOGRAPHICAL LOCATION CODES (STATES)

AL ALABAMA
AK ALASKA
AZ ARIZONA
AR ARKANSAS
CA CALIFORNIA
CO COLORADO
CT CONNECTICUT
DE DELAWARE
FL FLORIDA
GA GEORGIA
HI HAWAII
ID IDAHO
IL ILLINOIS
IN INDIANA
IA IOWA
KS KANSAS
KY KENTUCKY
LA LOUISIANA
ME MAINE
MD MARYLAND
MA MASSACHUSETTS
MI MICHIGAN
MN MINNESOTA
MS MISSISSIPPI
MO MISSOURI

MT MONTANA
NE NEBRASKA
NV NEVADA
NH NEW HAMPSHIRE
NJ NEW JERSEY
NM NEW MEXICO
NY NEW YORK
NC NORTH CAROLINA
ND NORTH DAKOLT
OH OHIO
OK OKLAHOMA
OR OREGON
PA PENNSYLVANIA
RI RHODE ISLAND
SC SOUTH CAROLINA
SD SOUTH DAKOTA
TN TENNESSEE
TX TEXAS
UT UTAH
VT VERMONT
VA VIRGINIA
WA WASHINGTON
WV WEST VIRGINIA
WI WISCONSIN
WY WYOMING

Figure A-19

Appendix G of AVSCOM PAM 750-1

APPENDIX G

GEOGRAPHICAL LOCATION CODES

EUROPE

BZ	BELGIUM
CZ	GERMANY
DZ	GREECE
EZ	ITALY
FZ	TURKEY

PACIFIC

AY	JAPAN
BY	KWAJALEIN
CY	KOREA

SOUTHERN

AX	PANAMA
BX	PUERTO RICO

Figure A-20

Ranking Sheet

PROGRAM — ACE

AIRCRAFT OH-6A

PAGE 1 OF 1

No.	INDICATOR NOMENCLATURE	CARD COL	WORST CASE CODE WTS.	INDICATOR CODES AND WEIGHTS (RANKED LEFT TO RIGHT)								CURVE WTS.
01	RTR HEAD ASSY MT FLT BEAM & FLOOR	47	E_{79}	X_{47}	C_{32}							79
02	FWD KEEL BEAM	39	E_{79}	B_{40}	C_{20}	D_{12}	Y_{7}					79
03	AFT L G/DRAG STRUT ATTACH AREAS	40	E_{79}	G_{40}	B_{24}	Y_{15}						79
04	CONTROL COLUMN	48	E_{79}	G_{40}	B_{26}	Y_{15}						79
05	FWD L G/DRAG STRUT ATTACH AREAS	38	E_{79}	G_{40}	B_{26}	Y_{15}						79
06	PAINT CONDITION	32	C_{79}	K_{47}	L_{32}							79
07	OVERALL CONDITION	31	C_{74}	K_{44}	L_{38}							74
08	TAILBOOM ATTACH FITTINGS	46	E_{64}	G_{32}	Z_{19}	Y_{13}						64
09	COCKPIT TRANSPARENCIES	33	C_{57}	E_{34}	X_{23}							57
10	FIREWALL F.S. 124	44	E_{51}	B_{26}	J_{15}	Y_{10}						51
11	AFT RING BULKHEAD	45	E_{46}	C_{23}	B_{14}	Y_{9}						46
12	PASS COMP BED L/H & R/H VENT WEBS	37	E_{42}	G_{21}	B_{13}	Y_{8}						42
13	UPPER EXTERNAL LONGERON R/H	41	E_{38}	G_{19}	Z_{11}	Y_{8}						38
14	UPPER EXTERNAL LONGERON L/H	42	E_{36}	G_{18}	Z_{11}	Y_{7}						36
15	AFT FUSELAGE SKIN, EXT & INTR	43	E_{33}	G_{17}	B_{9}	D_{5}	Y_{2}					33
16	CABIN DOORS L/H & R/H	36	E_{31}	F_{19}	Y_{12}							31
17	PASSENGER COMPARTMENT FLOOR	35	E_{29}	G_{15}	Y_{9}	Z_{5}						29
18	BATTERY COMPARTMENT	34	D_{27}	G_{16}	Y_{11}							27
19												
20												
21												
22												
23												
24												
25												
26												
27												
28												
29												
30												
31												
32												
33												
34												

DATE 6 MARCH 1984 APPROVED BY: Glenn R. Fuller

Figure A-21

Percent Weight Table
for Indicator Weight Distributions to Condition Codes

ACE INDICATOR CODE WEIGHTS

NUMBER OF INDICATOR CODES	% TOTAL WT WORST CASE CODE	% TOTAL WT SECOND CODE	% TOTAL WT THIRD CODE	% TOTAL WT FOURTH CODE	% TOTAL WT FIFTH CODE	% TOTAL WT SIXTH CODE
6.	100	50	20	15	10	5
5.	100	50	25	15	10	
4.	100	50	30	20		
3.	100	60	40			
2.	100	60				
1.	100					

NOTE: Worst case always receives 100% of the total weight (Prado's fixed wts). The total of the other indicator codes must be 100% or lower. It would be less than 100% if the added codes were less important than the subject percents in relation to the worst case.

CACI Extension of ACE Table to 8 Codes Used in ACEDARDS Program

NUMBER OF CODES	% OF TOTAL INDICATOR WEIGHT FOR CODES (Listed Worst to Best)							
	First Code	Second Code	Third Code	Fourth Code	Fifth Code	Sixth Code	Seventh Code	Eighth Code
8	100	35	25	15	10	7	5	3
7	100	40	25	15	10	6	4	
6	100	50	20	15	10	5		
5	100	50	25	15	10			
4	100	50	30	20				
3	100	60	40					
2	100	60						
1	100							

APPENDIX B

MATHEMATICS OF PARETO PRINCIPLE

APPENDIX B

B.1 The Pareto Principle

Vilfredo Pareto (1848-1923), an Italian philosopher, observed that a small percentage of the total population in his native Italy accounted for a large percentage of the country's wealth. This was generalized to the Pareto Principle of Maldistribution which, in essence, states that the significant or valuable items in a given group normally constitute a relatively small portion of the total items in the group. Conversely, a majority of the items in the group, even in the aggregrate, will be of relatively minor significance or value. This is "the significant few and the insignificant many" concept. It is also referred to as the "80/20" rule, where 80 percent of the value of a group is accounted for by 20 percent of the items in the group.

The Pareto principle seems to emerge in many widespread areas. Some examples of its almost universal applicability follow. In many inventories, 10 to 20 percent of the items account for 80 to 90 percent of the total dollar value of the inventory. The remaining large number of items then account for a very small portion of the inventory's dollar value. Similarly, 20 percent of the products of a company usually account for about 70 to 90 percent of its sales. A small percentage of a firm's employees normally cause a large percentage of the tardiness. Often, 10 percent of a firm's engineers may be responsible for 80 percent of its patents. In reliability analysis, a small percentage of the items of a system often cause the majority of the failures, or, stated another way, a large proportion of the failures in a product are due to a small number of causes. If failure data is analyzed in terms of the Pareto relationship, many of the minor causes can be eliminated from further analysis, and attention can then be focused on the few significant causes, namely, the "drivers" or "critical" items. This is the real value of the

Pareto principle. Spend time on the driving items, or solve the important problems first.

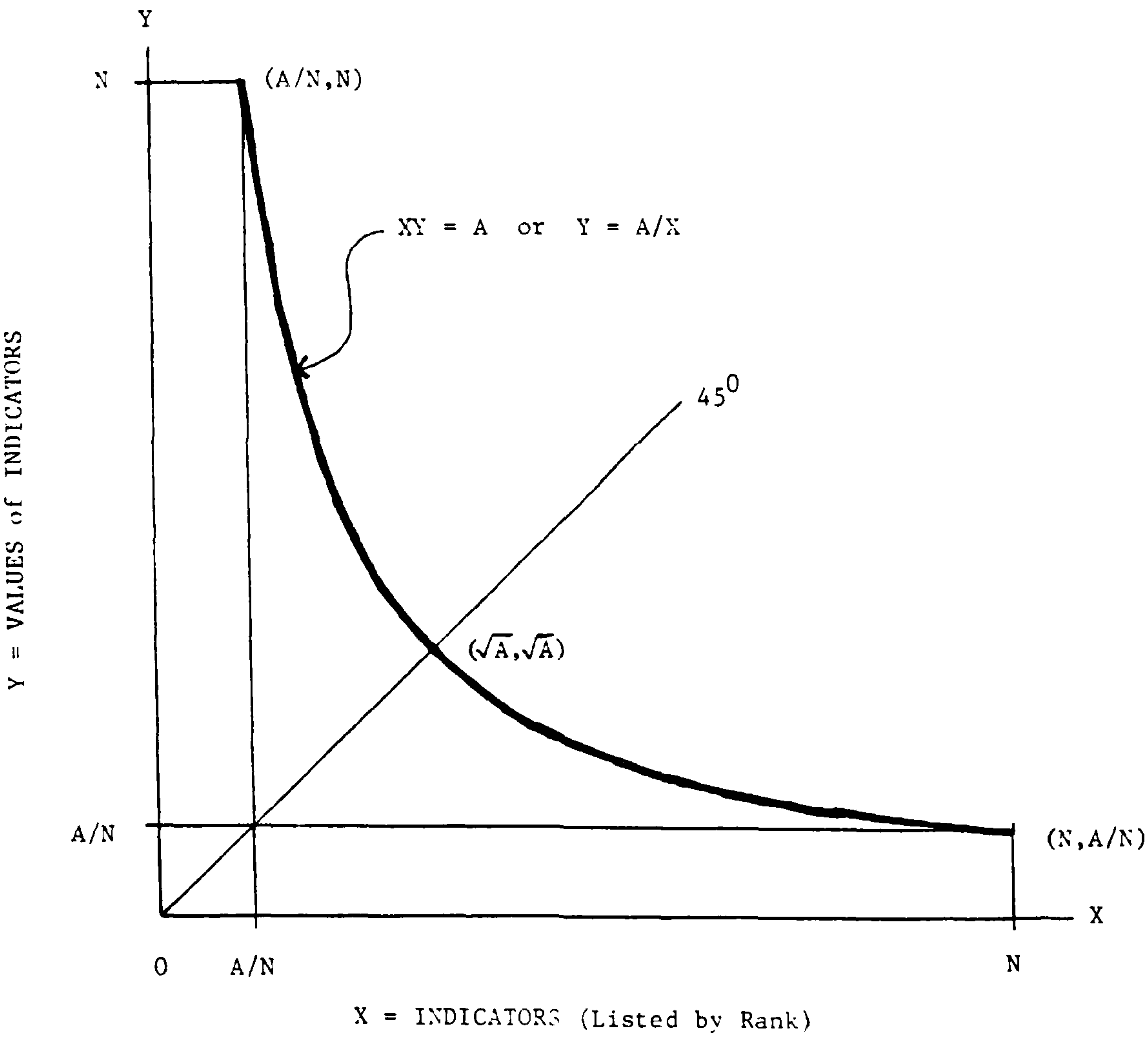
In the ACE program, this reliability application is the rationale behind the use of the Pareto concept in developing the indicator weights. It is assumed that a small percentage of the ACE indicators will cause a large percentage of the failures over the total aircraft population. These few drivers or critical indicators should be assigned the largest weights. Hence, the Pareto principle is applicable to the indicator weight distribution problem.

B.2 The Pareto Curve

The Pareto principle can be expressed mathematically as a curve of the form $X^K Y = A$, where X is the item or indicator of the group, Y is the value, ranking, or weight of the group, and K and A are constants which determine the shape of the curve. For reasons of simplicity and ease of use, the Pareto curve for ACE was selected to be of the form $XY = A$ (i.e., $K = 1$), and the curve is truncated at the points $X = N$ and $Y = N$, where N is the number of indicators. Therefore, X has a range equal to the number of indicators, and its intervals or units represent the indicators' rankings determined from the Emphasis Curve. The range of Y is the same as X's range, and its units provide cardinal values for the indicators' rankings (although these are not the final indicator weights). This is shown in Figure B-1. Figures 5 and 6 of the main report show other Pareto curves. Since X and Y have the same range and $K = 1$, this ACE form of the Pareto Curve is symmetric with respect to X and Y about the 45 degree line. (On the 45 degree line, $X = Y =$ the square root of A). Also, the intercepts of the curve with the truncation lines at $X = N$ and $Y = N$ occur at the points $(N,A/N)$ and $(A/N,N)$, respectively. Thus the number of indicators under the flat truncated portion of the left side of the curve is A/N. For example, when $N = 55$ and $A = 110$, the number of

Figure B-1

ACE Pareto Curve, XY = A

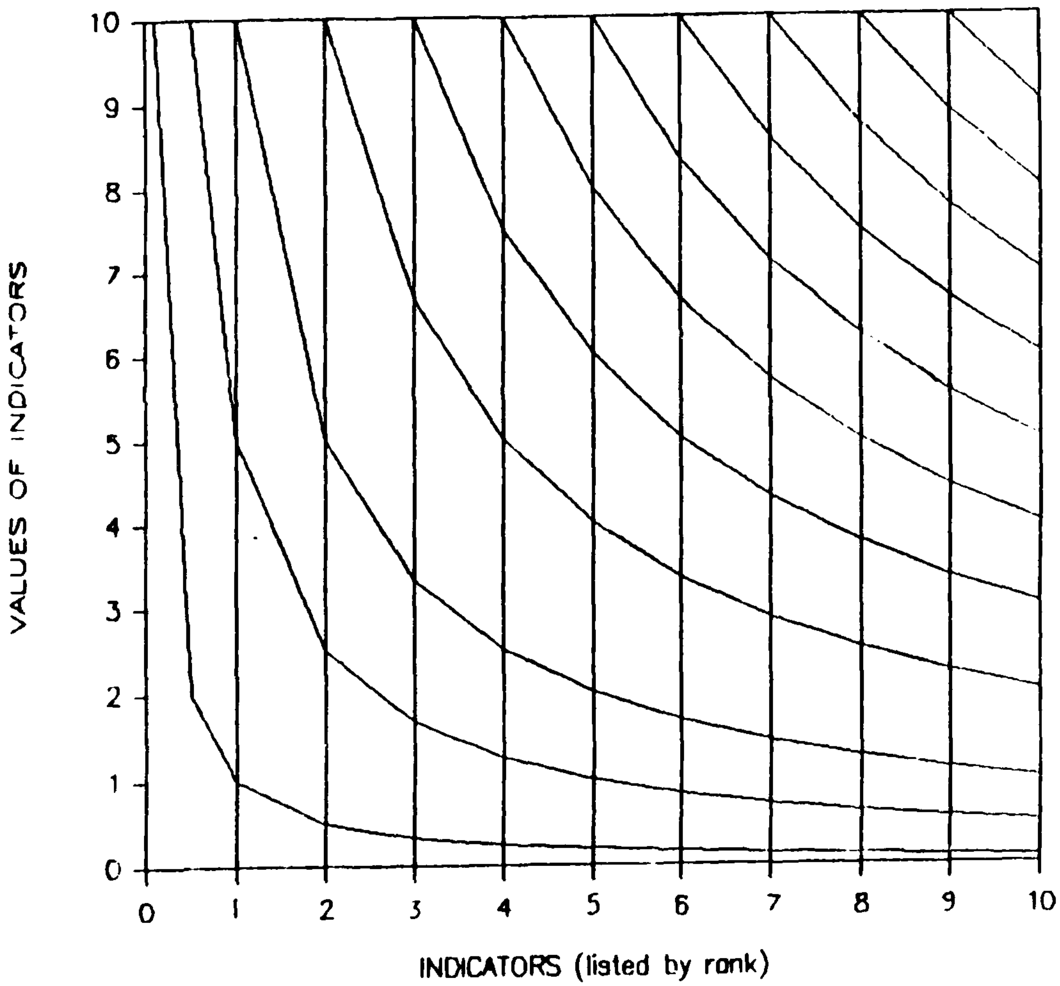


indicators under the top truncated portion of the curve is 110/55 = 2. Similarly, for A = 220, the number is 220/55 = 4. Note that these indicators can be considered as critical indicators, and they have equal importance and equal weight. Also, in the ACE form of the Pareto curve, the value of A alone determines the shape of the curve since K = 1. For any given number of indicators, the shape of the curve changes as A varies, and as the shape changes so does the distribution of the resulting indicator weights. The general shapes of the ACE Pareto curves are illustrated in Figure B-2 for 10 indicators (N = 10) and for A varying from 1 to 100. Note, due to the truncations at X = N and Y = N, the maximum value of A is N^2.

For a given number of indicators, the value of A determines not only the shape of the curve but how significant are "the few". Thus, A determines the percentage of the total weight that is caused by a given percentage of the indicators, e.g., the first 20% of the indicators determines 60% of the total weight. The larger the value of A, the smaller the percentage of weight for a given percentage of indicators, as shown in Figure B-2. So, as the value of A increases, the indicator weights become more evenly distributed (for A = N^2, all indicators have the same weight). Thus the value of A, and hence the shape of the curve, is a critical aspect of the ACE methodology. Based on their experience and prerogative, management can designate the shape of the curve and the resulting desired relative weight distribution of the indicators using various techniques. First, the value of A can be designated. Or, the value of A can be determined from a desired max/min ratio--the weight of the first and most critical indicator, having the maximum area under the curve, to the weight of the last and least significant indicator, having the minimum area under the curve. A third way to specify the shape of the curve is to have the first n number or P% of the indicators to yield Q% of the total weight. Finally, the number of indicators which lie under the flat truncated portion of the left side of the curve can be used to determine the value of A. How these techniques actually determine the value of A, and hence the shape of the curve, will be discussed in Section B.4 of this appendix.

Figure B-2

Shapes of the Pareto Curve



A	Max/Min	% Weight from 20% Ind	# Ind = A/N	% Ind = A/N
100	1.0	20.0	10	100
90	1.1	20.1	9	90
80	1.2	20.4	8	80
70	1.4	21.1	7	70
60	1.6	22.1	6	60
50	1.9	23.6	5	50
40	2.4	26.1	4	40
30	3.2	30.2	3	30
20	4.7	38.3	2	20
10	9.5	51.3	1	10
5	16.1	59.7	.5	5
1	31.3	71.3	.1	1

B.3 Areas Under the Curve and Indicator Weight Determination

The weight of an indicator is the ratio of the area under the curve of that indicator's ranking interval to the total area under the curve, multiplied by 1000.

The total area under the curve, TA, is found by integration. Here, log denotes the natural logarithm to the base e.

$$TA = (A/N - 0) \times N + \int_{A/N}^{N} A/X \, dX = A + A(\log N - \log(A/N)) = A(1 + \log(N^2/A)).$$

The area under the curve for any interval n-1 to n, IA, is illustrated in Figure B-3. The calculations for this area vary depending on the location of the interval with respect to the line $X = A/N$.

Case 1, where $n \leq A/N$:

$$IA = (n - (n-1)) \times N = N.$$

Case 2, where $n-1 \geq A/N$:

$$\begin{aligned} IA &= \int_{n-1}^{n} A/X \, dX \\ &= A(\log(n) - \log(n-1)) \\ &= A(\log(n/(n-1))). \end{aligned}$$

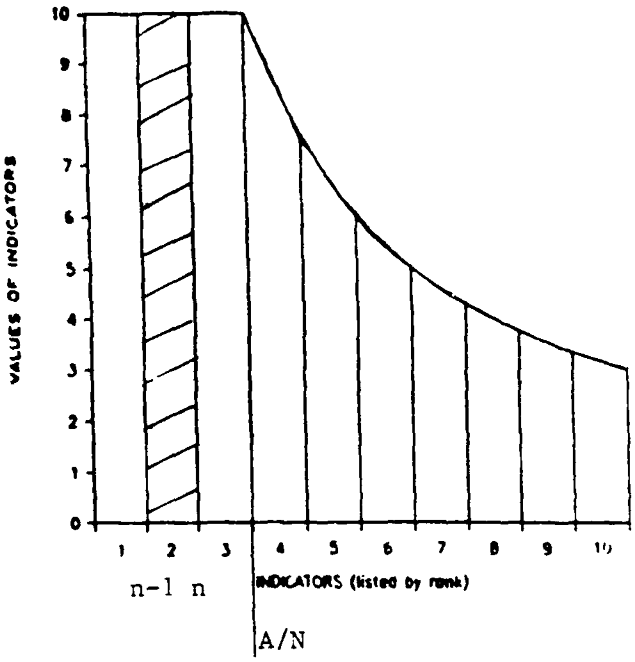
Case 3, where $n-1 < A/N < n$:

$$\begin{aligned} IA &= (A/N - (n-1)) \times N + \int_{A/N}^{n} A/X \, dX \\ &= A - (n-1)N + A(\log(n) - \log(A/N)) \\ &= A - (n-1)N + A(\log(nN/A)). \end{aligned}$$

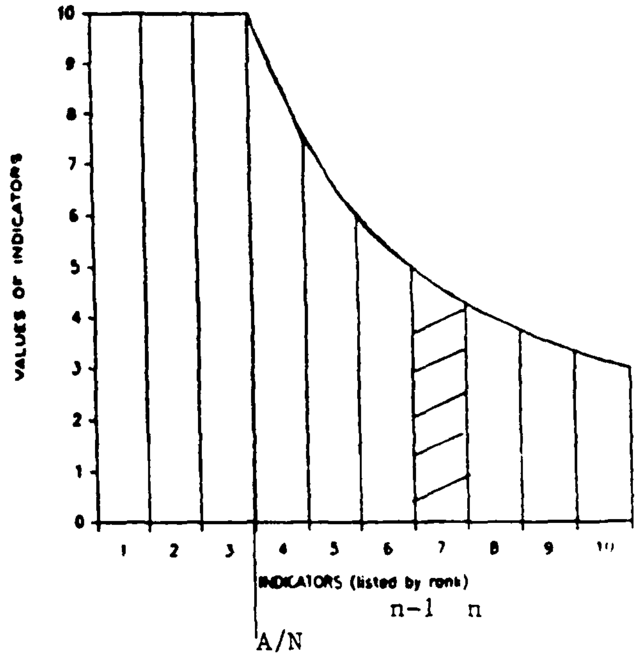
Thus, the indicator with rank n has a weight = IA/TA x 1000.

Figure B-3

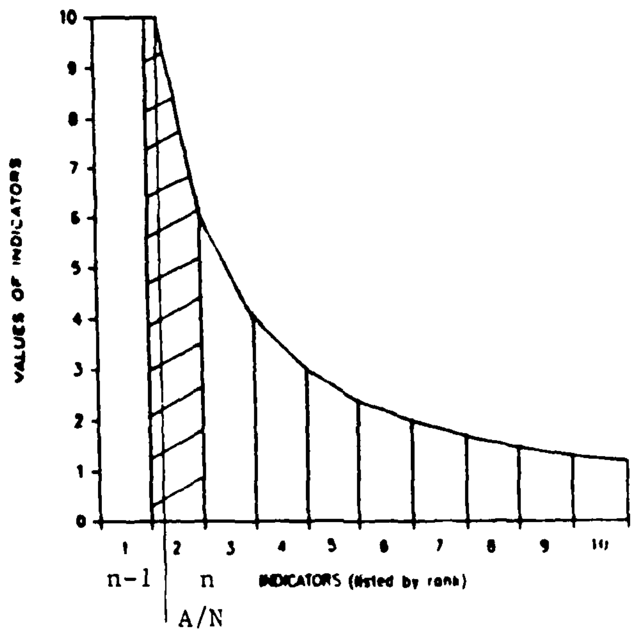
Area Under the Curve for an Interval n to n-1



Case 1, n ≤ A/N



Case 2, n-1 ≥ A/N



Case 3, n-1 < A/N < n

B.4 Determination of Curve Shape

Each of the four mentioned techniques for determining the value of A and hence the shape of the curve will be discussed, based on the given criteria.

B.4.1 Value of A

If the value of A is given outright, then the curve is provided directly, i.e., $XY = A$ or $Y = A/X$.

B.4.2 Max/Min Ratio

The max/min ratio, MMR, is defined as the ratio of the weight of the first and most critical indicator, having the maximum area under the curve, to the weight of the last and least significant indicator, having the minimum area under the curve. The area under the curve of the first indicator, whose interval is 0 to 1, will be designated as IA_{max}, and the area under the curve of the last indicator, whose interval is N-1 to N, will be designated as IA_{min}. These areas are shown in Figure B-4 (for N = 10). The calculations for these areas vary depending on where the first and last intervals lie with respect to the line $X = A/N$. Based on the calculations for IA_n shown in Section B.3, IA_{max} and IA_{min} are calculated as follows.

Case 1, where $1 \leq A/N \leq N-1$:

$$IA_{max} = (1 - 0) \times N = N.$$

$$IA_{min} = \int_{N-1}^{N} A/X \, dX = A(\log(N) - \log(N-1)) = A(\log(N/(N-1))).$$

Case 2, where $1 > A/N$:

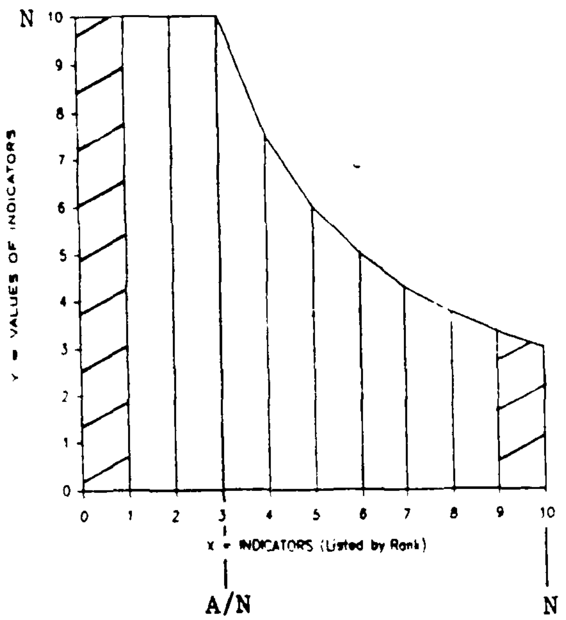
$$IA_{max} = (A/N - 0) \times N + \int_{A/N}^{1} A/X \, dX = A + A(\log(1) - \log(A/N))$$

$$= A + A(\log(N/A)) = A(1 + \log(N/A)).$$

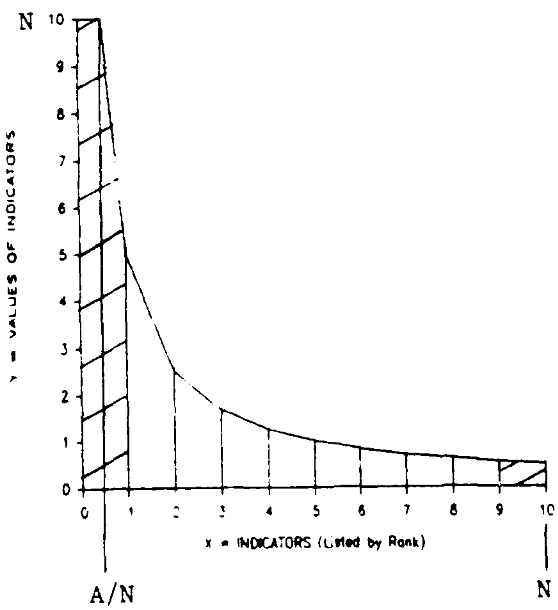
$$IA_{min} = \int_{N-1}^{N} A/X \, dX = A(\log(N) - \log(N-1)) = A(\log(N/(N-1))).$$

Figure B-4

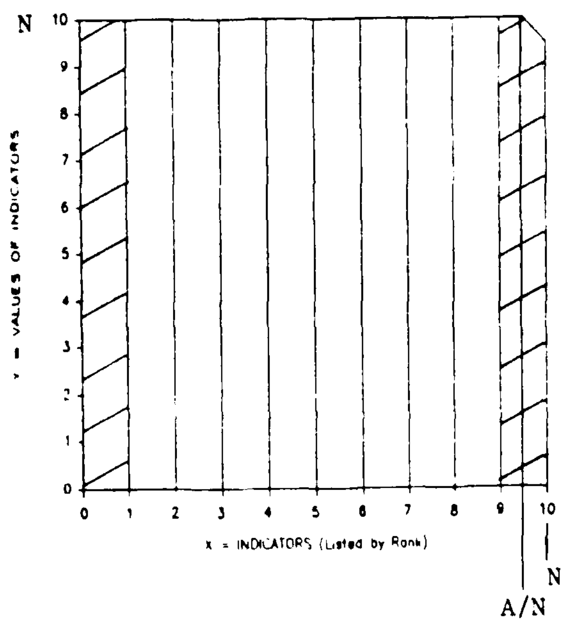
Max/Min Relationship



Case 1, $1 \leq A/N \leq N-1$



Case 2, $1 > A/N$



Case 3, $N-1 < A/N$

Case 3, where $N-1 < A/N$:

$$IA_{max} = (1 - 0) \times N = N.$$

$$IA_{min} = (A/N - (N-1)) \times N + \int_{A/N}^{N} A/X \, dX$$

$$= A - (N-1)N + A(\log(N) - \log(A/N))$$

$$= N(1-N) + A(1 + \log(N^2/A)).$$

Now, $MMR = (IA_{max}/TA \times 1000) / (IA_{min}/TA \times 1000) = IA_{max}/IA_{min}$.

Therefore, if MMR is given, then

Case 1: $MMR = N / (A(\log(N/(N-1))))$.

Solving this for A gives, $A = N / (MMR \times \log(N/(N-1)))$.

Case 2: $MMR = A(1 + \log(N/A)) / (A(\log(N/(N-1))))$

$$= (1 + \log(N/A))/(\log(N/(N-1))).$$

Solving this for A gives, $A = e^{(1 + \log(N) - (MMR \times \log(N/(N-1))))}$.

Case 3: $MMR = N / (N(1-N) + A(1 + \log(N^2/A)))$.

This can not be solved directly for A, so a successive approximation technique such as Newton's can be used.

B.4.3 First n or Q% of Indicators Yields P% of Total Weight

The area under the curve of the first n or Q% of the indicators, whose interval is 0 to n ($n = .Q \times N$, where $.Q = Q\%/100$), will be designated as QA. This is illustrated in Figure B-5 (for N = 10), and the calculations for this area vary depending on where the interval 0 to n is with respect to the line $X = A/N$.

Case 1, where $n \leq A/N$:

$$QA = (n - 0) \times N = n \times N.$$

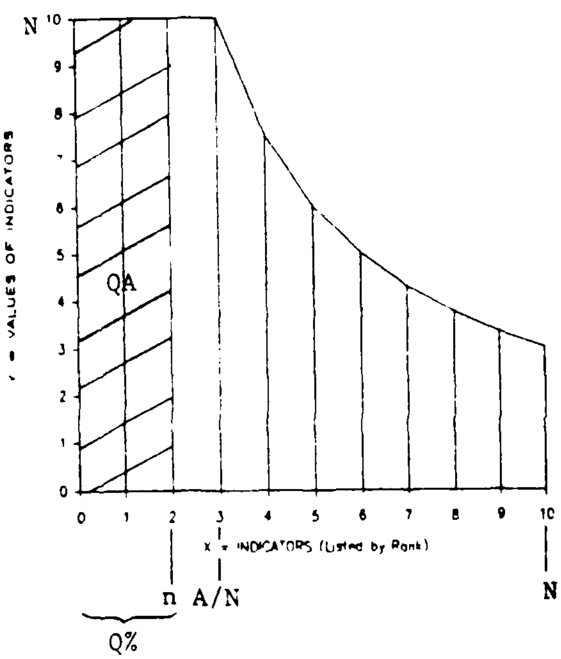
Case 2, where $n > A/N$:

$$QA = (A/N - 0) \times N + \int_{A/N}^{n} A/X \, dX$$

$$= A + A(\log(n) - \log(A/N)) = A(1 + \log(nN/A)).$$

Figure B-5

Q% of Indicators Provides P% of Weight



Case 1, $n \leq A/N$ Case 2, $n > A/N$

$n = Q\%/100 \times N$

TA = Total Area Under Curve

$P\% = QA/TA \times 100$

Now $.P = P\%/100 = (QA/TA \times 1000) / (TA/TA \times 1000) = QA/TA.$

Therefore, if $.P$ and (n or $.Q$) are given, then

Case 1: $$.P = (n \times N) / (A(1 + \log(N^2/A)))$$

$$= (n/N \times N^2) / (A(1 + \log(N^2/A)))$$

$$= (.Q \times N^2) / (A(1 + \log(N^2/A))).$$

This can not be solved directly for A, so a successive approximation technique such as Newton's can be used.

Case 2: $$.P = A(1 + \log(nN/A)) / (A(1 + \log(N^2/A)))$$

$$= (1 + \log((n/N)N^2/A)) / (' + \log(N^2/A))$$

$$= (1 + \log(n/N) + \log(N^2/A)) / (1 + \log(N^2A))$$

$$= 1 + \log(n/N) / (1 + \log(N^2/A))$$

$$= 1 + \log(.Q) / (1 + \log(N^2/A)).$$

Solving this for A gives, $A = e^{(\log(n/N)/(1-.P) + 1 + \log(N^2))}$

$= e^{(\log(.Q)/(1-.P) + 1 + \log(N^2))}.$

B.4.4 First n or Q% of Indicators Lie Under Flat Truncated Portion of Left Side of Curve

This approach also provides the curve directly. Since A/N is the number of indicators under the flat truncated portion of the left side of the curve, then n must equal A/N. If Q% is given, then $n = .Q \times N$, where $.Q = Q\%/100$. Figure B-6 depicts this relationship (for N = 10).

Thus, if n or .Q is given, then

$$n = A/N.$$

Solving for A gives, $A = n \times N = .Q \times N^2$.

Figure B-6

Q% of Indicators Lies Under
Flat Truncated Portion of the Curve